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We're finally going there to find out

NewScientist

WEEKLY February 28 - March 6, 2015

EXCLUSIVE

HEAD TRANSPLANTS

Inside the two-year plan to swap old bodies for new ones



PLUS

TOUCH

The sense that shapes our minds

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Mini versions of
giant experiments

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Like a car. But be



Fuel consumption figures mpg (litres/100km) and CO₂ emissions (g/km), Audi A3 Sportback e-tron: Urban: N/A, Extra Urban: N/A, Combined/ test results: one when the battery is fully charged and the other when the battery is discharged. The two test results are a weighted average, petrol engine generating electricity. Standard EU Laboratory Test figures are for comparative purposes between vehicles and may not reflect

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The new Audi A3 Sportback e-tron.

etter_



WHATCAR?

**Car of the
Year 2015**

Best electric car

weighted: 176.6 mpg (1.6 litre/100km). CO₂ emissions: 37g/km. The 'Combined/weighted' fuel consumption CO₂ figures calculated from two taking into account mileage range on battery power only, providing a figure in a variety of charge conditions. Extended range achieved by 1.4 TFSI real driving results. Images for illustration purposes.

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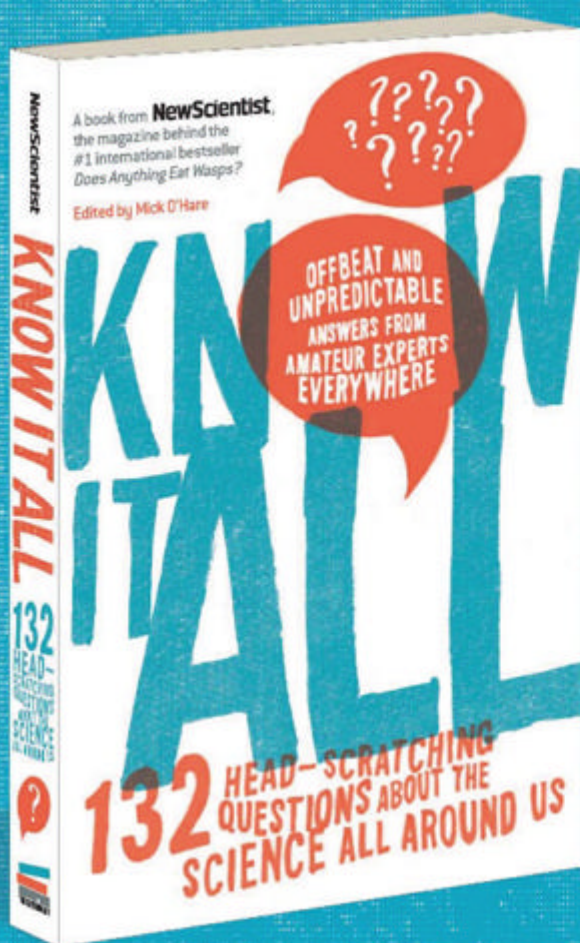
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THE BAFFLING, TRIVIAL, CURIOUS, OR STRANGE . . . KNOW IT ALL



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ANDREW HOLBROOKE/CORBIS

The ultimate makeover

Body swaps sound like fantasy, but they pose real questions

HAVE you ever wondered what happens to an amputated limb? People can remain emotionally attached to their detached flesh, but they can't do whatever they want with it. A severed arm can't be formally cremated, for example, because a death certificate is required for that. So hospitals may incinerate a limb like any other waste, then return its ashes to their owner – perhaps to be reunited after their death.

But what if it's not just a single limb at stake, but an entire body? This week, we report surgeon Sergio Canavero's plan to transplant a living head onto a donated body by 2017. He believes it won't be long before someone tries it, and that going public with his plan will help stimulate debate over its practical and ethical implications (see page 10).

We began imagining such grafts centuries ago. One telling has it that the Hindu god Ganesha was beheaded by his father and revived thanks to a donated elephant's head. Fast-forward to the 1920s, and H. P. Lovecraft was writing about Herbert West preserving severed heads in a "vat of pulpy reptile-tissue", ready to be attached to fresh bodies. Today, heads or brains in jars are a staple of pop culture, mostly played for horror, sometimes for comedy.

Add to that our special dread of decapitation, which anyone who has been watching the news lately will appreciate, and this is not a promising milieu against which to launch such a radical proposal. Transferring a head to a new body is being touted as a solution to inoperable cancers, quadriplegia and inexorable diseases like amyotrophic lateral sclerosis, the condition that Stephen Hawking

"Transferring a head to a new body is being touted as a solution to inoperable cancers"

has. But even if it works – a big if – would we ever sanction its use?

It certainly isn't going to be a comfortable discussion. Many specialists contacted by *New Scientist* flatly refused to discuss Canavero's ideas, dismissing them as outlandish or unethical. To be fair to them, this may be because Canavero has yet to describe some aspects of his proposed protocols in the detail they deem necessary for a proper debate. However, every advance in transplantation has seemed outlandish at first, from hearts to hands to faces, but in each case, doubts have given way to appreciation.

On the ethics, they have a point. Any attempt, even if it falls short

of Canavero's ambitions, would raise serious questions. For a start, we don't know how a donated body will feel. Organ donation is now a simple matter of restoring internal function, but we use our bodies to interact with the world: they are intertwined with our sense of self (see page 34).

Then there is the question of who, if anyone, should qualify to have the procedure. The cases of those with terminal illness or drastic physical impairment may be relatively simple to assess. But what about those with identity issues? People with body dysmorphias go to extraordinary lengths to have healthy but unwanted limbs removed: will they take desperate measures to rid themselves of their bodies?

And if it were to be successful, how would body swaps affect our ideas about the end of life? Those planning to freeze their heads in the hope of revival might now be one step closer to their goals. Will we – or more likely, a chosen few – one day be able to simply swap bodies to extend our lives?

On the basis of past experience, you can safely bet on there being an outcry if and when the first operation is attempted. Far better if the debate is held before any particular individuals become its focus. ■



Connected to real muscle

Mind moves bionic hands

BIONIC hands are go. Three men with serious nerve damage had their hands amputated and replaced by prosthetic ones that they control with their minds. The procedure, dubbed “bionic reconstruction”, was carried out by Oskar Aszmann at the Medical University of Vienna, Austria.

The men had all suffered accidents that damaged the brachial plexus – the bundle of nerve fibres that runs from the spine to the hand. Despite attempted repairs to those nerves, the arm and hand remained paralysed.

Before the operation, Aszmann’s patients had to prepare their bodies and brains. First he transplanted leg muscle into their arms to boost the signal from the remaining nerve fibres. Three months later, after the nerves

had grown into the new muscle, the men started training their brains. First they practised activating the muscle using an armband of sensors that picked up on the electrical activity. Then they moved on to controlling a virtual arm. Finally, Aszmann amputated their hands, and replaced them with a standard prosthetic under the control of the muscle and sensors (*The Lancet*, DOI: 10.1016/S0140-6736(14)61776-1).

After the transplant all three were able to pick up a ball, pour water from a jug and do up buttons. On a standard assessment measure, they improved their average score from 9 out of 100 to 65. “We’re rethinking the wiring of the body,” says Dustin Tyler of the Louis Stokes Veterans Affairs Medical Center in Ohio.

Champion gamer

YOUR top score is about to be trounced. Google has developed artificial intelligence software capable of learning to play video games just by watching them.

Google DeepMind, a London-based subsidiary, has trained

“It scored highly on arcade classic *Breakout* and even managed to learn a trick seasoned players use”

an AI gamer to play 49 different video games, beating a professional human player’s top score in 23 of them.

The software isn’t told the rules of the game – instead it uses an algorithm called a deep neural network to examine the state of the game and figure out which actions produce the highest total score.

“It really is the first algorithm that can match human performance across a wide range of challenging tasks,” says DeepMind co-founder Demis Hassabis.

The software performed best

on simple pinball and boxing games, but also scored highly on the arcade classic *Breakout*, which involves bouncing a ball to clear rows of blocks. It even managed to learn to tunnel through one column of bricks and bounce the ball off the back wall, a trick that seasoned *Breakout* players use (*Nature*, DOI: 10.1038/nature14236). “That was a big surprise,” says Hassabis.

Google won’t say why it’s interested in the software, but it could be used to analyse large datasets and to improve the ads the company serves up.

Wind energy rising

RENEWABLE sources of energy like wind turbines could soon generate more electricity in the UK than nuclear power stations.

The contribution of renewables towards keeping the lights on more than doubled from 6.8 per cent in 2010 to 14.9 per cent in 2013, according to the Office of National Statistics. Nuclear power, at 19 per cent, is in slow decline – no new power stations have been built since 1995, when nuclear contributed more than 25 per cent of the UK’s electricity.

Onshore wind turbines delivered a third of the country’s renewable energy in 2013, with offshore wind farms rising fast and accounting for 21 per cent.

The UK has invested £14.5 billion in wind turbines since 2010, supporting 35,400 jobs, says Ed Davey, secretary of state for energy and climate change.

The gap between wind and nuclear energy is closing fast, says Gordon Edge of Renewable UK, which represents the wind industry. “Renewables are set to overtake nuclear on a permanent basis by the end of next year.”



Andy dreams of moon glory

Race on the moon

GET ready for wacky races. The first off-planet race could be between three rovers across the surface of the moon. At stake is the Google Lunar XPrize and \$20 million, going to the first team to successfully land on the moon, travel 500 metres, and send images back to Earth.

Astrobiotic, a space logistics firm in Pittsburgh, Pennsylvania, announced plans in December to launch its rover, Andy, from Cape

Canaveral in time for the deadline at the end of 2016, sending it up aboard a SpaceX Falcon 9 rocket.

Now, Astrobiotic has agreed to let Japanese space company Hakuto piggyback its rovers, Moonraker and Tetris, on the launch. If the three rovers successfully travel together, it might mean we'll see the first-ever sprint to the finish on lunar soil – what Astrobiotic CEO John Thornton describes as “NASCAR on the moon”.

“It should be an exciting race,” says Andrew Barton of XPrize, though he says several technical challenges remain.

Sceptic scrutinised

A PROMINENT climate change sceptic may see his work re-examined by journals after Greenpeace revealed he had not disclosed funding from fossil-fuel companies.

Wei-Hock “Willie” Soon, an aerospace engineer with the Harvard-Smithsonian Center for Astrophysics, has published several papers arguing that global warming is caused by solar activity. His work is cited by climate sceptics such as US senator James Inhofe.

Kenneth Heideman of the American Meteorological Society, which published one of Soon's papers, says: “AMS is investigating the facts and will make a decision regarding the disposition of the paper once all of these have been considered.”

Several of Soon's papers appeared in the *Journal of Atmospheric and Solar-Terrestrial Physics*. “While we have not yet determined what action the journal will take, the publisher has made it clear that such allegations are taken very seriously,” says Robert Strangeway, its editor.

Greenpeace's collaborator in the probe, the Climate Investigations Center, will notify all the journals involved of the findings.

Malaria drug failing

RESISTANCE to a vital drug against malaria has spread across Burma, reaching the Indian border. Unless contained, it could spread to India, then Africa, which has 90 per cent of the world's malaria cases.

Resistance to artemisinin drugs first appeared in Cambodia in 2007, then reached southern Burma. Resistant malaria parasites have mutations in a gene called *K13*. Now the mutant genes have been found in the blood of people with malaria in northern and eastern Burma. In fact, the genes showed up in more than a

fifth of samples from seven of Burma's 10 provinces – and in nearly half the samples from a clinic only 25 kilometres from the border with India (*The Lancet Infectious Diseases*, doi.org/2d2).

“The main threat is the spread of artemisinin resistance from Burma to India,” says Didier Menard of the Pasteur Institute in Phnom Penh, Cambodia. Because of widespread infection and the sheer size of the population, the burden of malaria in India is huge. Recent studies suggest little resistance there so far but, says Menard, a study like the Burmese one needs to be done as soon as possible.

India's pollution toll - in life years

DON'T take a deep breath.

Air pollution in India is robbing its citizens of an estimated 2.1 billion years of life collectively.

India is home to 13 of the world's top 20 cities for particulate air pollution, according to the World Health Organization. To gauge its impact, Michael Greenstone at the University of Chicago compared levels of fine particulates across India and used a model to convert those levels into the number of years of life lost. He found 55 per cent of Indians – or 660 million people by the 2011 census – live in areas with dangerous levels of particulates. These people can expect a 3.2 year cut to their lifespans – a total of 2.1 billion years.

While the number of years of

life lost to air pollution is higher in China – a previous study estimated 500 million people were collectively losing 2.5 billion years – China has started to do something about it, says Joshua Apte of the University of Texas in Austin. “China is ahead of India in terms of formulating local and national-level policies to tackle pollution.”

The US government is hoping that installing particulate monitors on the roof of its New Delhi embassy will encourage the Indian government to act. It claims this worked in Beijing, where the US has been measuring air quality since 2008. The move is part of a plan to install monitors in several countries, starting with India, Vietnam and Mongolia.

APRESS ASSOCIATION IMAGES



An insidious killer

60 SECONDS

Climate resignation

The chair of the Intergovernmental Panel on Climate Change (IPCC), Rajendra Pachauri, 74, has resigned after being accused of sexually harassing a 29-year-old female researcher at his New Delhi-based research group. The move comes ahead of this week's IPCC meeting in Nairobi. Vice-Chair Ismail El Gizouli has been promoted to acting chair.

Allergy rethink

Peanuts are a no-go for kids, right? Not necessarily. For years, this advice has been given to parents to avoid triggering a nut allergy – but it may be out-dated. Children regularly given foods containing peanuts before age five were 17 times less likely to develop a peanut allergy than children whose parents avoided giving them peanuts (*New England Journal of Medicine*, doi.org/2dx).

Hot, sweaty... healthy?

Saunas don't just make you sweat, they may also help your heart. A study of 2315 Finnish men showed that those who indulged in between four and seven sauna sessions a week had a 63 per cent lower risk of sudden cardiac death than those who took one session per week. The risk of fatal coronary heart disease was 48 per cent lower for the regular users (*JAMA Internal Medicine*, doi.org/2dz).

Martian deadline

Mars One, the Dutch firm hoping to colonise the Red Planet, has just a few months to decide whether it will launch its first uncrewed mission to Mars in 2018. If it misses the deadline, the entire enterprise will be delayed by two years.

Tiger trouble

An increase in tiger numbers claimed by the Indian government has been put in doubt. Biologists say the index-calibration method used to estimate numbers can produce inaccurate results (*Methods in Ecology and Evolution*, doi.org/2d3).

Welcome to the body shop

Surgeon launches two-year plan to carry out a human head transplant

Helen Thomson

IT'S heady stuff. The world's first attempt to transplant a human head will be launched this year at a surgical conference in the US. The move is a call to arms to get interested parties together to work towards the surgery.

The idea was first proposed in 2013 by Sergio Canavero of the Turin Advanced Neuromodulation Group in Italy. He wants to use the surgery to extend the lives of people whose muscles and nerves have degenerated or whose organs

until its immune system rejected the head. Although few head transplants have been carried out since, many of the surgical procedures involved have progressed. "I think we are now at a point when the technical aspects are all feasible," says Canavero.

This month, he published a summary of the technique he believes will allow doctors to transplant a head onto a new body (*Surgical Neurology International*, doi.org/2c7). It involves cooling the recipient's head and the donor body to extend the time their cells can survive without oxygen.

The tissue around the neck is dissected and the major blood vessels are linked using tiny tubes, before the spinal cords of each person are cut. Cleanly severing the cords is key, says Canavero.

The recipient's head is then moved onto the donor body and the two ends of the spinal cord – which resemble two densely packed bundles of spaghetti – are fused together. To achieve this, Canavero intends to flush the area with a chemical called polyethylene glycol, and follow up with several hours of injections of the same stuff. Just like hot water makes dry spaghetti stick together, polyethylene glycol encourages the fat in cell membranes to mesh.

Next, the muscles and blood supply would be sutured and the recipient kept in a coma for three or four weeks to prevent movement. Implanted electrodes would provide regular electrical stimulation to the spinal cord, because research suggests this can strengthen new nerve connections.

When the recipient wakes up, Canavero predicts they would be able to move and feel their face and would speak with the same

voice. He says that physiotherapy would enable the person to walk within a year. Several people have already volunteered to get a new body, he says.

The trickiest part will be getting the spinal cords to fuse. Polyethylene glycol has been shown to prompt the growth of spinal cord nerves in animals, and Canavero intends to use brain-dead organ donors to test the technique. However, others are sceptical that this would be enough. "There is no evidence that the connectivity of cord and

brain would lead to useful sentient or motor function following head transplantation," says Richard Borgens, director of the Center for Paralysis Research at Purdue University in West Lafayette, Indiana.

If polyethylene glycol doesn't work, there are other options Canavero could try. Injecting stem cells or olfactory ensheathing cells – self-regenerating cells that connect the lining of the nose to the brain – into the spinal cord, or creating a bridge over the spinal gap using stomach membranes

"If society doesn't want a head transplant, I won't do it but that doesn't mean it won't be done somewhere"

are riddled with cancer. Now he claims the major hurdles, such as fusing the spinal cord and preventing the body's immune system from rejecting the head, are surmountable, and the surgery could be ready as early as 2017.

Canavero plans to announce the project at the annual conference of the American Academy of Neurological and Orthopaedic Surgeons (AANOS) in Annapolis, Maryland, in June. Is society ready for such momentous surgery? And does the science even stand up?

The first successful head transplant, in which one head was replaced by another, was carried out in 1970. A team led by Robert White at Case Western Reserve University School of Medicine in Cleveland, Ohio, transplanted the head of one monkey onto the body of another. They didn't attempt to join the spinal cords, though, so the monkey couldn't move its body, but it was able to breathe with artificial assistance. The monkey lived for nine days



CHITHRAUNNI/GETTY

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have shown promise in helping people walk again after spinal injury. Although unproven, Canavero says the chemical approach is the simplest and least invasive.

But what about the prospect of the immune system rejecting the alien tissue? Robert White's monkey died because its head was rejected by its new body. William Mathews, chairman of the AANOS, says he doesn't think this would be a major problem today. He says that because we can use drugs to manage the acceptance of large amounts of tissue, such as a leg or a combined heart and lung transplant, a head transplant should be possible. "The system we have for preventing immune rejection and the principles behind it are well established."



Which one would you have?

Canavero isn't alone in his quest to investigate head transplants. Xiao-Ping Ren of Harbin Medical University in China recently showed that it is possible to perform a basic head transplant in a mouse (*CNS Neuroscience & Therapeutics*, doi.org/2d5).

The essence of you

Another hurdle will be finding a country to approve such a transplant. Canavero would like to do the experiment in the US, but believes it might be easier to get approval somewhere in Europe. "The real stumbling block is the ethics," he says. "Should this surgery be done at all? There are obviously going to be many people who disagree with it."

Patricia Scripko, a neurologist and bioethicist at the Salinas Valley Memorial Healthcare System in California, says that many of the ethical implications related to the surgery depend on how you define human life. "I believe that what is specifically human is held within the higher cortex. If you modify that, then you are not the same human and you should question whether it is ethical. In this case, you're not altering the cortex." However, she adds that many cultures would not approve of the surgery because of their belief in a human soul that is not confined to the brain.

As with many unprecedented procedures, there may also be concerns about a slippery slope. In this case, it would be whether this would eventually lead to people swapping bodies for cosmetic reasons. However, Scripko – who doesn't believe the surgery will ever happen – doesn't think this applies here. "If a head transplant were ever to take place, it would be very rare. It's not going to happen because someone says 'I'm getting older, I'm arthritic, maybe I should get a body that works better and looks better'."

Unsurprisingly, the surgical community is also wary of

embracing the idea. Many surgeons contacted by *New Scientist* refused to comment on the proposed project, or said it sounded "too outlandish" to be a serious consideration.

"This is such an overwhelming project, the possibility of it happening is very unlikely," says Harry Goldsmith, a clinical professor of neurological surgery at the University of California, Davis, who has performed one of the few surgeries that enabled someone with a spinal cord injury to regain the ability to walk. "I don't believe it will ever work, there are too many complications. Trying to keep someone healthy in a coma for four weeks – it's not going to happen."

Nick Rebel, executive director of the US branch of the International College of Surgeons, says that although his organisation, along with the AANOS, is giving Canavero a stage, it is not sponsoring his ideas. "We're creating a venue for him to launch the project. There will be a lot of top international surgeons at the conference and we shall see whether it is well received or not."

Mathews is more enthusiastic about the project. "I embrace the concept of spinal fusion," he says, "and I think there are a lot of areas that a head transplant can be used, but I disagree with Canavero

"If it gets the go-ahead, it's not going to be done just because someone is old and arthritic"

on the timing. He thinks it's ready, I think it's far into the future."

Canavero is philosophical. "This is why I first spoke about the idea two years ago, to get people talking about it," he says. "If society doesn't want it, I won't do it. But if people don't want it in the US or Europe, that doesn't mean it won't be done somewhere else. I'm trying to go about this the right way, but before going to the moon, you want to make sure people will follow you." ■

THE BIG QUESTIONS

What's the difference between brain and head transplants?

A brain transplant would involve removing the brain from the skull and placing it in a donor skull. It is more difficult than a head transplant because of the complex surgery to separate the brain and blood supply without damaging delicate tissue.

Could the transplant technique work for a cryogenically frozen head?

No. The proposed technique requires a healthy human head and brain. It is not yet known whether it is possible to "defrost" a cryogenically frozen head and resurrect healthy brain tissue.

Would the surgery be psychologically damaging?

Some people who have received face or limb transplants mourn the loss of their old body part or feel that their self image is conflicted. Studies show that inputs from our body, such as a heartbeat or rumbling stomach, can influence our will power, emotions and language. Who knows whether the person who comes out of the operating room would be the same as the one who went in.

Would there be any benefits apart from getting a healthier body?

If the recipient head is older than the donor body, they may get a rejuvenating boost. Infusions of young blood can raise physical endurance and cognitive function in older animals. A study is now seeing if young blood has the same effect on people with Alzheimer's.

I'm a registered organ donor. Could my body be used for this?

Each country has its own rules. In the UK, joining the register would not automatically allow your body to be used. "If a person needs something not specified on our forms, we would ask a potential donor's family to consent," says an NHS spokesperson. "We would only approach a family if the planned procedure had ethical approval."

Seeking alien life in Europa's icy seas

Adam Mann

HOW do you solve a problem like Europa? The icy moon of Jupiter is thought to host a vast ocean beneath its frozen crust, making it an ideal target to look for life beyond Earth. But the tiny world also has a perfect storm of problems – a poorly mapped surface, a space environment full of powerful radiation, geysers that may or may not exist – that make designing such a mission tricky.

Last week, more than 200 scientists and engineers met at NASA's Ames Research Center in Mountain View, California, to chart a course for detecting life in Europa's seas. This isn't mere wishful thinking: NASA's 2016 budget gave a dedicated mission to the icy moon the green light, with a launch date for the probe by the mid-2020s.

"We're going to do a Europa mission," NASA science administrator John Grunsfeld told the meeting. "If there's something trapped in that water, and we potentially have the opportunity to see it, it could be transformative."

For decades, mission planners assumed that any probe sent to explore Europa's watery secrets would need to land on the surface, drill through the ice and swim through the inky deep. That changed in 2013, when a team used Hubble data to conclude that 200-kilometre-tall geysers were spraying from near Europa's south pole. All engineers would need to do is reach orbit to taste the moon's interior.

That's good news for the best-studied mission design, a \$2.1 billion concept known as the Europa Clipper. To avoid Jupiter's harsh radiation belts, the Clipper wouldn't land on the moon's

surface or even orbit it directly, but instead orbit Jupiter and make regular fly-bys of Europa.

If the geysers are active when an orbiter passes by, it could fly through the spray and collect a sample. But how do we tell if anything lives in it? The instruments scientists typically use to find microbes in droplets on Earth are too bulky and finicky to send across the solar system. Instead, astrobiologists rely on a technique known as mass spectrometry, which identifies the chemicals in a sample.

The presence of organic molecules could be a clue to

"We're going to do a Europa mission but the clock is ticking. I hope we don't miss this opportunity"

life, but they can also form through abiotic processes. Complex organic molecules are much tougher to randomly assemble. Only life can put together something as intricate as chlorophyll, for instance, which has a long hydrocarbon tail and a flower-like head containing nitrogen, oxygen and magnesium.

"The probability of this just forming in high abundance is essentially zero," Lee Cronin of the University of Glasgow, UK, told the meeting as he presented his "universal life detector". This would use mass spectrometry to identify complex chemicals, with the assumption that a high number is a hint of life.

Another idea is to use an array of antibodies, the chemicals your immune system produces to recognise invaders. Antibodies have evolved to grab hold of just about any organic molecule and could be arranged on a chip to snag and categorise chemicals in a Europa sample, suggested Chris

McKay of NASA Ames. He also pushed the idea of checking the biochemicals for their chirality, or handedness. Life on Earth only uses left-handed amino acids, and life elsewhere might have a similar preference.

We might not catch them alive, though. Any Europa microbes shot out of a geyser would be boiled and then fried in Jupiter's powerful radiation. But that doesn't bother McKay: a freshly killed microbe has the same biochemistry as a living one. "Death is just another form of life," he said.

Ice punch

But it might not be that easy. Europa's geysers haven't been spotted again, suggesting they are either relatively rare, or the initial observation was a fluke.

Charles Hibbitts of Johns Hopkins University in Baltimore, Maryland, has an alternative idea: punch through the ice. We could smash a precision impactor into



Home sweet home?

DETLEV VAN RAVENSWAAY/SCIENCE PHOTO LIBRARY

Europa's surface and send the orbiting spacecraft through the resulting plume to collect a sample, similar to NASA's Deep Impact mission, which shot a projectile at a comet in 2005.

If we find evidence of past plume activity on Europa, that would be the perfect place to dive bomb, Hibbitts said, because it might increase our odds of hitting the subsurface ocean.

Rather than rely on a robot, some would like to get a bit of Europa back to Earth. Isik Kanik of NASA's Jet Propulsion Laboratory presented a modified version of his team's Life Investigation For Enceladus (LIFE) mission, originally designed to capture a sample from Saturn's geyser-erupting moon Enceladus and bring it home. He described a sample return mission as "the gift that keeps on giving", because the samples "can be analysed and reanalysed for generations to come".

There's just one problem: even a small sample would take a lot of additional fuel to climb out of Jupiter's colossal gravity.

Small and dedicated might be the way to go. A proposal from David Mauro of NASA Ames called Europa Plume Chaser would send two small satellites to Jupiter, each carrying a camera and some miniaturised instruments. The first would scout for plumes, hopefully giving scientists enough information to direct the second probe through a plume. Tiny satellites have the potential to transform deep space science, and even *New Scientist* is getting in on the action with our TEENSY mission, a crowdfunded spacecraft for Europa exploration.

A mission to Europa has a lot of wind in its sails. But instruments will have to be selected soon to make the targeted launch date. As it may be decades before NASA sends another probe we should make an effort to find life now. "The clock is ticking," Grunsfeld said. "I just hope we don't miss this remarkable opportunity." ■

INSIGHT Assisted suicide



AP PHOTO/COMPASSION & CHOICES

Brittany Maynard chose when to die

US states grapple with the right to die

THE fight to legalise doctor-assisted suicide for people who are terminally ill will take centre stage in the US this year, with bills filed in 20 states plus the District of Columbia.

"I think it's a watershed year," says Peg Sandeen, head of the non-profit Death with Dignity, based in Portland, Oregon, which campaigns for doctors to be able to prescribe lethal doses of barbiturates to terminally ill people. The practice is already legal or has been decriminalised in five states.

Sandeen says public opinion may have shifted significantly after Brittany Maynard, a 29-year-old with terminal brain cancer, moved to Oregon last year, where doctor-assisted suicide is legal. A video by Maynard in which she explained her reasons for choosing assisted suicide has been watched over 11 million times.

Maynard ended her life in November, but her story has given the existing death-with-dignity movement new momentum. Bills were recently filed in New York and California, two of the country's most politically influential states. Assisted suicide has just been legalised in Canada, after similar lawsuits there, although it will be a year before the law takes effect.

The outcome of the legal battles that are likely to ensue in the US are hard to predict. Assisted suicide faces

opposition from religious groups as well as disability activists, who say it implies that those who are disabled, old or ill have lives that aren't worth living – and that people could be pressured into it.

Diane Coleman, head of advocacy group Not Dead Yet, which opposes assisted suicide, says the Oregon Health Authority's annual reports on the practice show the law there isn't working as intended. She points to the motives people gave for choosing this

they feel they are a burden. "To me that feels more like a duty to die than a choice to die," she says.

What's more, according to the data available for Oregon, some people waited longer than six months between asking for the overdose and taking it. It isn't stated how many times this happened, but at least some people lived a few years after obtaining the drugs. Coleman is concerned that this means people are being accepted for assisted suicide who don't meet the criteria of having less than six months to live. "Those people were not actually terminally ill," she says.

Sandeen, however, says that while doctors sometimes underestimate how long people have to live, this is rare. She adds that the small number of people choosing assisted suicide – 105 in Oregon last year out of a population of around 4 million – is reassuring. "That should give other states solace that they will have the same experience – that it will be a rarely used option."

In the UK, the Supreme Court ruled last year that parliament should re-examine the issue as there is a "real prospect" of a future legal challenge succeeding. "There's an appetite for this now," says Jacky Davis, chair of Healthcare Professionals for Assisted Dying. **Clare Wilson** ■

"A video in which Maynard explains why she chose assisted suicide has been watched 11 million times"

option. According to the latest figures, released on 12 February, only a third of people who took a prescribed lethal dose of medication in 2014 cited pain or fear of pain as one of the reasons for doing so.

Supporters of assisted suicide often cite pain as a primary reason why people should have the legal right to die. But the state's report showed that people's concerns tended toward loss of autonomy (91 per cent), loss of dignity (71 per cent) or being a burden on their family (40 per cent). Coleman is particularly concerned that people are choosing assisted suicide because

Giant black hole grew too fast

Jacob Aron

THAT sure is a flaming big hole. Astronomers have discovered a black hole with a mass 12 billion times that of the sun. It seems to have reached that size when the universe was less than a billion years old, which creates a puzzle. Current models suggest that it could not have grown so big so soon after the big bang.

Xue-Bing Wu of Peking University in Beijing, China, and his colleagues found the black hole by searching through data from sky surveys, looking for bright objects called quasars.

One candidate, J0100+2802,

looked particularly promising, so the team used telescopes in China and the US to analyse its light. By measuring how much the light had been stretched out by the expansion of the universe, they calculated that it is 12.8 billion light years from Earth.

Quasars, which emit vast quantities of light, are thought to surround black holes and be powered by gas heating up and glowing as it falls into the hole. Measuring the properties of this gas can in turn determine the black hole's mass. J0100+2802 is about four times as bright as the previous brightest quasar at this distance, and its black hole is a monster at

12 billion times the mass of our sun (*Nature* DOI: 10.1038/nature14241).

There are bigger black holes out there, but it is the age of this one that's troubling. It reached this size just 900 million years after the big bang – which in black hole terms isn't very long.

"Everyone thinks of black holes as these great dangerous things that swallow up anything in their vicinity," says Daniel Mortlock of

"If you try to force-feed a black hole, you get a traffic jam on the way in and everything heats up"

Imperial College London. But that's not the case. "If you try to force-feed it you get a traffic jam on the way in and it gets very dense."

This heating creates quasars, but if too much material falls in too quickly, it becomes hot enough to force new material out

of the gravitational pull of the black hole. Such an early giant breaks the theorised growth limits, says Wu. "It either requires very special ways to grow the black hole, or requires that a huge seed black hole existed when the universe was less than 300 million years old."

Another explanation is that small black holes somehow form in clusters in the early universe, and grow massive by merging with each other rather than sucking up gas, says Mortlock. But large black holes made this way won't glow, so we can't see them.

None of these solutions is fully supported by existing theories, says Mortlock, so we will probably need bigger telescopes to peer even further back into the past. "You're coming up with theories to try to explain what are pretty close to the most distant objects we can see," he says. ■

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Gerbils and Silk Road to blame for the plague

IT WASN'T the rats after all. Cute little gerbils, not their much-despised cousins, may have caused the Black Death in Europe in 1347, as well as prompting repeated outbreaks of plague over the next four centuries.

Plague is caused by the *Yersinia pestis* bacterium, which is carried by fleas and mostly affects rodents. Europe has been hit by plague a number of times, but the second pandemic - the one that caused the Black Death - is the most notorious.

The disease is believed to have originally arrived in Europe from Asia via the Silk Road trading route. But the repeated outbreaks from the Black Death onwards have been blamed on rat reservoirs in Europe: bacteria-infested fleas hiding out in rats.

But Nils Christian Stenseth at the

University of Oslo, Norway, and colleagues say that instead of rats, their furry counterparts - probably gerbils and marmots - in central Asia were to blame.

The team analysed 4119 post-Black Death plague outbreaks and found that the vast majority probably spread from outbreaks nearby. But Stenseth identified 61 separate outbreaks that took place in 17 harbour areas, including London and Hamburg, that are likely to have been caused by maritime imports from Asia.

By comparing these cases with historical records, Stenseth's team was able to identify 16 years in which brand new introductions of *Y. pestis* were probably responsible for plague outbreaks, as opposed to infection from neighbouring regions.



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Cute but deadly

They found that climate fluctuations in Asia - above average temperatures followed by sudden drops - consistently preceded plague reintroductions in Europe (PNAS, DOI: 10.1073/pnas.1412887112). This could be because, under warmer conditions, fleas become more active and the rodents they live on more numerous. When the temperature

drops, rodent populations crash and the fleas are forced to find new hosts.

Climate fluctuations are likely to affect wildlife plague reservoirs today, too, says Stenseth. "In central Asia and northern China, the current climate change is likely to increase the occurrence of plague, whereas in the southern part of China it is likely to decrease." Penny Sarchet ■



BRITISH AIRWAYS

FIELD NOTES Mount Kenya



RHINO ARK

Keeping them apart

Fencing up wildlife in Kenya's forests

Fred Pearce

"WE REMEMBER the elephants. It was frightening," 10-year-old Moses told me as we walked amid the tea gardens on the lower southern slopes of Mount Kenya, the second-highest mountain in Africa. "But they are locked up now. We are safe when we walk to school."

The first 70 kilometres or so of the world's longest conservation fence has been completed in the area (see map, right). Stretching 500 kilometres when finished, and electrified to 8000 volts, it will surround the entire mountain – one of the world's great refuges for wildlife – and keep animals away from villages.

The rights and wrongs of electric fences that keep humans and wildlife apart have become a battleground in the debate about how best to preserve megafauna.

A couple of hours' drive to the west, beneath the Aberdare mountains, which have been encircled by a 400-kilometre fence since 2009, the people of Bondeni village sing the barrier's

praises. "Once this place was dangerous; people were killed by water buffalo and leopards ate their livestock," said village head Peter Kibuka. "We needed food aid because the animals trampled our crops. But now we are safe and can grow all our own food."

This goes against the traditional view among conservation scientists that fences damage wildlife by isolating populations, preventing migration and causing inbreeding. But those who oppose fences may be basing their views

on the ideal of unspoiled and remote places, losing perspective on what's happening in human-modified landscapes with intense land use pressures, Marion Pfeifer of Imperial College London told me. In fact, wildlife can thrive in fenced areas: one study by Pfeifer and colleagues found that African lions had significantly denser populations in fenced reserves.

The Aberdares fence was initiated by a local charity, Rhino Ark, to protect rhinos on the mountain. The group is also largely funding and building the fence around Mount Kenya.

Fence-building has now been adopted by government agencies like the Kenya Wildlife Service, which approve and help maintain the fences. "The big

issue here is conflicts between wildlife and communities," says Simon Gitau, the warden of Mount Kenya National Park. "The fence will bring harmony, so I am in favour of it."

Local wardens say that reducing conflicts between farmers and animals encourages villagers to report poachers and the outsiders that recruit them, meaning fences may also help keep animals safer. And there are plans to create new migration corridors to other wildlife areas, which should alleviate problems such as inbreeding caused by isolating populations of large animals.

The next step will be to maintain the fences, says Christian Lambrechts, who runs Rhino Ark. He is installing remote monitors that can identify the location of power outages. Often they can also indicate whether the problem is a stray branch, which would cause a continuous outage, or a poacher, which would cause a brief one.

"Once this place was dangerous; people were killed by water buffalo and leopards ate the livestock"

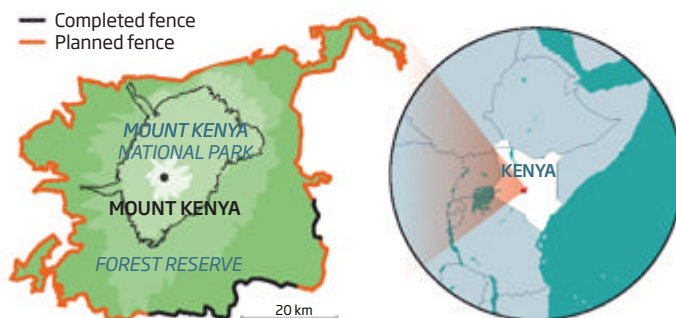
Not everybody is happy with the fences, though. Members of the Ogiek tribe traditionally lived in one newly fenced upland, the Eburu forest, west of the Aberdares. In a heavy-handed government operation, they were thrown out of the fenced area. But they are now negotiating, with the help of Rhino Ark, to be given land close to the fence that will allow them access to their hundreds of forest beehives.

The last Ogiek still living in the forest with his family, Maseto Mebarne, does so with the consent of local officials and now has a job as a fence warden. "If it wasn't for us the forest wouldn't be there. But there are so many outsiders round here today that we need the fence to conserve the forest." ■

Rhino Ark funded Fred Pearce's trip

Locked up

The world's largest conservation fence will keep people and wildlife separate in Kenya. At 500km long, it will encircle the forest reserve surrounding Mount Kenya



Did sponge microbiomes help aerate the oceans?

APPEARANCES apart, they are no spongers. Tiny bacteria living inside sponges seem to be symbiotic and may have played a part in the drama that transformed Earth's deep oceans 750 million years ago. This upheaval turned seas into the oxygen-rich haven for life so familiar to us today.

The discovery of the curious bacteria was an accident, says Fan Zhang of the University of Maryland in Baltimore. He and his colleagues happened to notice microscopic phosphate granules spread throughout the tissue of three different species of Caribbean sponges they had in the lab. Living inside the sponges were bacteria that suck phosphorus out of seawater and precipitate it into granules. The team proposes how sponges and bacteria

live in symbiosis to make the most of the phosphorus in the water for their own nutrition (PNAS, DOI: 10.1073/pnas.1423768112). Phosphorus is a rare but essential nutrient for ocean life. Sponges need it to survive but can't extract it from the water.

Meanwhile, bacteria rely on the sponges to pump vast amounts of seawater over them so they can extract more phosphorus. So, Zhang says, the sponges and bacteria live in symbiosis.

That is interesting because sponges and many of the symbiotic bacteria that Zhang found in his samples have been around for hundreds of millions of years, since the early days of animal life on Earth. Around 750 million years ago the deep oceans were flooded with oxygen.

This transformation was traditionally credited with driving the Cambrian explosion, the sudden flourishing of all the different types of animal shapes we know today (see page 38).

Nicholas Butterfield of the University of Cambridge and his colleagues proposed last year that early animals, specifically sponges, led to a surge in deep ocean oxygen, not the other way around.

They pointed out that sponges can

"Early animals could have actually exerted significant controls over Earth's ancient chemistry"

survive on very low levels of oxygen and are great at pumping and filtering water. "Invent something like a sponge [750 million years ago] and the world is their oyster. They have no competition. And now, for the first time water is being pumped and filtered," says Butterfield.

As the sponges pumped, they aerated the deep oceans with oxygen, he says. Phosphorus in the water would have reacted with that oxygen to form a hard phosphate precipitate, drastically reducing the amount of nutrients available to oxygen-consuming life forms, hence further boosting oxygen levels in the deep. Zhang and his colleagues' study offers an interesting explanation for how the sponges and their symbiotic bacteria might have sequestered and regulated phosphate in the early ocean, says Butterfield.

"It has largely been thought that early animals evolved rather passively in response to physical and chemical changes on the early Earth," says Daniel Brady Mills of the University of Southern Denmark in Odense. "Studies like this suggest that early animals could have actually exerted significant controls over Earth's ancient chemistry."

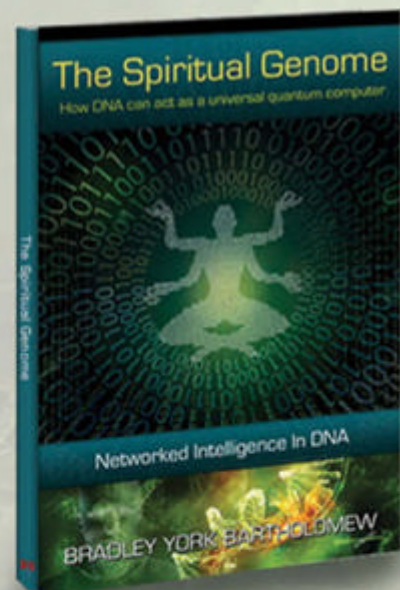
Catherine Brahic ■

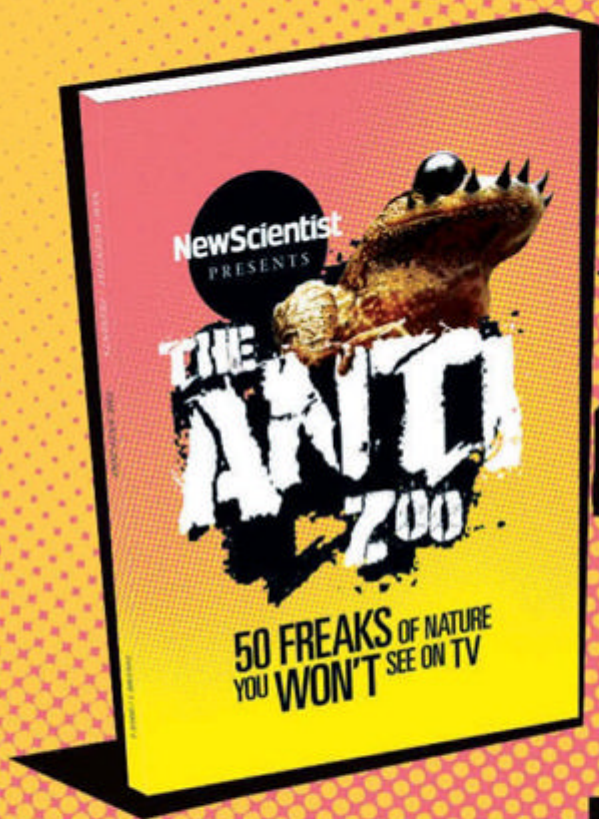
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Dragonfly eyes see the world in ultra-multicolour

THEIR massive globular eyes should have been a clue. It turns out dragonflies have souped-up colour vision that's better than anything ever seen in the animal world.

We humans have what's known as tri-chromatic vision, which means we see colours as a combination of red, blue and green. This is thanks to three different types of light-sensitive proteins in our eyes, called opsins. We are not alone: di-, tri- and tetra-chromatic vision is de rigueur in the animal world, from mammals to birds and insects.

Enter the dragonfly. A study of 12 dragonfly species has found that each one has no fewer than 11, and some

a whopping 30, different visual opsins (*PNAS*, DOI: 10.1073/pnas.1424670112).

Ryo Futahashi of the National Institute of Advanced Industrial Science and Technology in Tsukuba, Japan, also found dragonflies use different opsins at different ages. For instance, the larvae of some species that hatch in sand tend to lack blue opsins. "This is probably because blue light does not reach them easily," he says.

Do all those extra opsins mean dragonflies see the rainbow differently to us? Probably. Other studies have found that dragonflies can see ultraviolet, on top of blue, green and red. And it is thought that they can recognise polarised light coming off reflective surfaces like water. "It's likely that they have better colour discrimination than humans," says Futahashi.

Hormone stops rats from getting drunk

CHEERS! If you want to counteract the effects of getting drunk, a shot of the "cuddle chemical" oxytocin might be the answer.

Oxytocin plays a role in sexual behaviour and social bonding. While investigating the chemical's known effect on alcohol cravings, Michael Bowen from the University of Sydney, Australia, noticed something strange – rats given a dose of

it didn't seem to get drunk.

"Those that had the oxytocin were up and moving about as if they hadn't had any alcohol at all, whereas the ones that didn't have oxytocin were quite heavily sedated," Bowen says.

The chemical appears to counteract alcohol by binding to GABA receptors in the brain, the same ones on which alcohol exerts its intoxicating effects

(*PNAS*, DOI: 10.1073/pnas.1416900112). Bowen hopes his findings will lead to a drug that doesn't just prevent drunkenness, but also helps alcoholics cope with withdrawal.

However, the effects in rats weren't limitless. While oxytocin prevented drunkenness in those that had been given the equivalent of a bottle and a half of wine, its effects did not extend as far as the rat-sized equivalent of a whole bottle of vodka.

Buckyballs play a different sport

FORGET football, buckyballs are bouncing around the volleyball court these days. Volleyballene is the first buckyball to be spiked with scandium atoms.

Discovered in 1985, the original buckyball was a hollow, stable sphere of 60 carbon atoms. It takes high temperatures and pressures without complaint and helped earn its creators a Nobel prize in chemistry in 1996.

Volleyballene has 60 carbon atoms moulded into pentagons, plus 20 scandium atoms locked in octagons, an arrangement that resembles the panels of a volleyball ([arXiv.org/abs/1502.03507](https://arxiv.org/abs/1502.03507)).

Jing Wang at Hebei Normal University in China and colleagues tested five other configurations to see if a different mash-up proved easier to make, stronger, or more stable. Only volleyballene held its shape up to 727 °C, or 1000 kelvin.

Brace yourself for burst of warming

CONSIDER yourself warned. We can expect a burst of supercharged warming when the pause in rising global temperatures finally ends.

Global mean surface temperatures have not risen significantly since about 1998, which could be because oceans are sucking up the extra heat.

If this turns out to be the case, Chris Roberts from the Met Office in the UK and colleagues have found that there is a 60 per cent chance the hiatus will be followed by a five-year period of rapid warming at twice the usual background rate (*Nature*, DOI: 10.1038/NCLIMATE2531).

The models also suggest there is a 15 per cent chance the hiatus will continue for five more years.

Sun still harms after going inside

TIME to slap on the “evening-after” sunscreen. Sun can damage your skin hours after you’ve gone inside.

Melanoma, the deadliest form of skin cancer, is linked to exposure to UV rays. These rays cause kinks in DNA, called cyclobutane pyrimidine dimers. CPDs ultimately cause the mutations that can lead to cancer.

A team led by Douglas Brash at Yale University noticed that mouse skin cells continue to form CPDs up to 3 hours after irradiation with UV light – but only the cells containing melanin, the pigment responsible for skin colour (*Science*, DOI: 10.1126/science.1256022). “The melanin, which is supposed to be protecting us, is also doing something harmful,” says Brash.

The team found that UV light activates two enzymes that combine to chemically excite an electron in melanin. The energy of this electron then gets transferred to the DNA in the cell, causing the production of CPDs. Once activated, the enzymes remain active for several hours, continuing to produce these “dark CPDs”.

The team thought there could be ways to block the delayed effects, using antioxidants to absorb the excited electrons before they damage DNA. Sure enough, when the antioxidant ethyl sorbate was added to irradiated skin cells, it prevented dark CPDs from forming.



MARTIN BARRAUD/GETTY

Searching for signs of Mars life could destroy them

WHOOOPS. Martian minerals could destroy organic compounds – the molecules necessary for life – as we search for them.

To analyse rock samples, the Curiosity rover now exploring the Red Planet grinds them into powder and heats them in an oven. But some compounds break down and release an oxygen atom when heated, which splits any organic molecules in the sample.

James Lewis at Imperial College London and his colleagues wanted to examine jarosite, a mineral found in previously watery areas

on Mars. They gathered samples from Brownsea Island in Dorset, UK, and analysed them as Curiosity would by heating them at a range of temperatures.

“We never detected the organics we knew were in the sample,” he says. Instead, they found sulphur dioxide, carbon dioxide, carbon monoxide and water – which would be expected if the jarosite reacted with the organics and broke them down into other carbon compounds. “If Curiosity was doing a similar experiment on Mars, and had a compound

with jarosite and organics, it wouldn’t be able to detect them.”

This isn’t just a problem for Curiosity, which isn’t tasked with searching for signs of life today. The European Space Agency’s ExoMars rover, due to launch in 2018, will hunt for life – and also uses a heating technique.

But there is hope. Jarosite and related minerals come in many different forms, some of which don’t fall apart until they reach much higher temperatures – so choosing the right samples will be key (*Astrobiology*, doi.org/2cs).

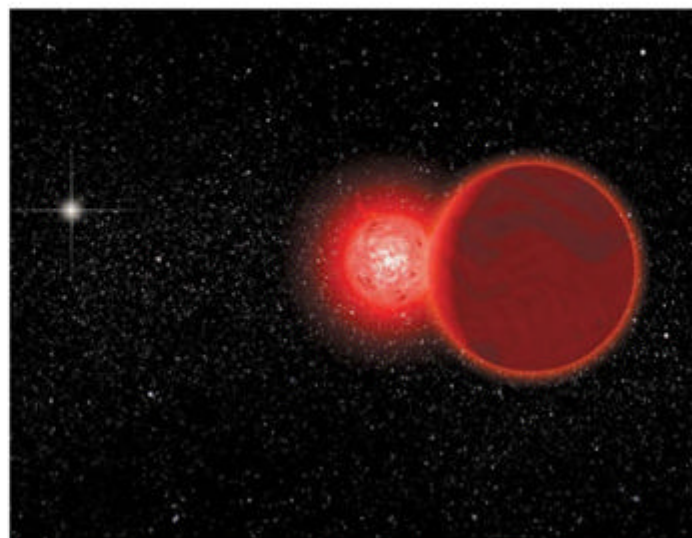
Oral sex could save a spider’s life

IF YOU’RE a male spider, mating can be deadly – it often ends in being eaten by the female. But the Darwin’s bark spider might have found a way around this hazard. During mating, they orally lubricate females’ genitals.

Until now, little was known of the behaviour of these Madagascan spiders (*Caerostris darwini*). A team led by Simona Kralj-Fiser at the Slovenian Academy of Sciences and Arts in Ljubljana observed that during mating the males nibble on the females’ genitalia, leaving behind a liquid that looks like digestive juice. Kralj-Fiser suggests that the act relaxes females so they are less likely to engage in cannibalism.

“The spiders are an enigmatic species, but even we were in for a surprise when we observed their courtship behaviour,” says Kralj-Fiser, who presented the work at an Ethological Society conference in Hamburg, Germany, this month.

Her team found that 76 per cent of females were aggressive to males, with 35 per cent cannibalising them after mating. While oral lubrication may help avoid this, males didn’t bother doing so with young females, which are unable to do them harm.



MICHAEL OSADCIW/UNIVERSITY OF ROCHESTER

Stellar intruder flew past the sun

A SPEEDING star whizzed through the outer solar system about 70,000 years ago. The visitor, a dim red dwarf, came within a light year of the sun, making it the closest known approach by a star.

Eric Mamajek of the University of Rochester in New York and his colleagues say it appears to be moving very slowly sideways across the sky, but is in fact moving away from Earth at an astounding 80 kilometres a second and is now 20 light years away. That pattern of motion suggests it recently came close to the sun.

The team performed 10,000 simulations to determine what path the star was likely to have taken. In 98 per cent of them, it passed through the solar system’s outer fringes – a comet-filled region called the Oort cloud – about 70,000 years ago (*Astrophysical Journal Letters*, doi.org/2cgg).

It was a close call: the star probably came within 0.8 light years of the sun but was too small and fast to have an effect on any planets. “It was like a tiny hummingbird flying through,” says Mamajek. But it may have been bright enough for our ancestors to see.



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Heavy metal is so last year

Aluminium that is as cheap as steel will make our world a nimbler, greener place, says **Hal Hodson**

TESLA'S electric sports car; the Audi A8; Lockheed's SR-71 spyplane: only the fastest, sleekest vehicles and aircraft have been made from high-grade aluminium, magnesium and titanium. These wonder metals are light and strong, but have a downside, namely their high cost and the large amounts of energy needed to produce them. Only the rich and powerful have enjoyed their benefits – until now.

"If all US planes and cars used lightweight metals, it would cut carbon emissions by 5 per cent"

The US government is funding a group of projects that aim to unleash light metals for the masses. Run by the Department of Energy's research arm ARPA-E, the METALS programme aims to make

aluminium and magnesium cost the same as steel, while titanium could become as cheap as the slightly pricier stainless steel.

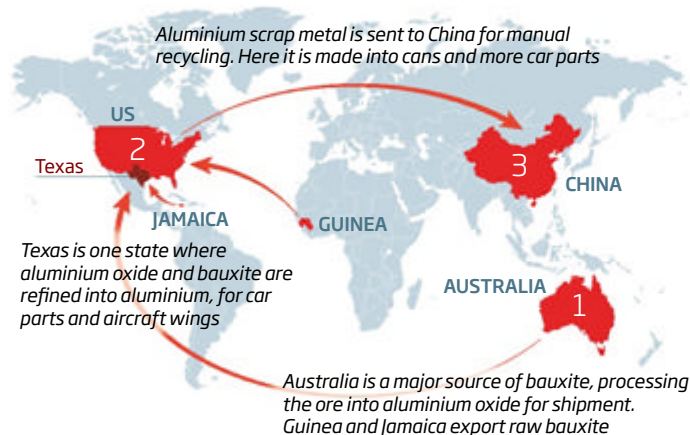
Last week 18 teams presented their work at ARPA-E's annual energy innovation summit in Washington DC, showing new ways to produce these metals and handle valuable scrap.

ARPA-E's primary goal is to reduce the energy that goes into transport – by making cars and planes lighter. The immediate benefit would be to make them a whole lot zippier and more energy-efficient, and there are many other exciting possibilities further down the road (see "Talented Titanium", right).

Steel is much used in motor vehicles and load-bearing structures, like bridges. Aluminium, magnesium and titanium would be better in

Metal merry-go-round

Vast amounts of energy and money are pumped into mining, producing and recycling aluminium around the world



most cases, but are prohibitively expensive.

"Titanium is the best structural metal there is," says James Klausner, who leads METALS. "It's lightweight, it's strong and it lasts forever because it does not corrode." He sees titanium potentially displacing steel – if the price would only fall from \$35 to \$4 per kilogram.

ARPA-E's stance is that reducing the energy cost of light metal production would benefit the US in the same way as its recent glut of cheap gas, by bringing it closer to energy independence. "Light metal production consumes a lot of energy," says Klausner. "If you're importing metal from overseas, that's tantamount to importing energy." Better, he says, "to use our domestic ore to produce domestic metal".

Massachusetts-based Infinium is one firm aiming to revolutionise aluminium

production. It is exploiting a new kind of electrochemical cell that separates the metal from its ore without generating carbon dioxide, a by-product of traditional methods. Chief technology officer Adam Powell says their process is 30 per cent more energy-efficient, and the company is already producing rare earth metals like neodymium and dysprosium in this way.

Magnesium is present in huge quantities in the ocean, but at such low concentrations that extracting it is very energy-intensive. At the Pacific Northwest National Laboratory in Richland, Washington, researchers have partly solved that problem, using a catalyst that reduces the working temperature of the process from 900 to 300°C.

By bringing the energy cost down and making lightweight metals the stuff of everyday manufacturing, ARPA-E hopes



There must be a better way

there will be other major benefits too. According to Klausner, “lightweighting” all cars and planes in the US would save 121 billion litres of fuel a year and cut carbon emissions by about 5 per cent.

But if such projects succeed, we will have to tackle another

challenge – recycling these light metals. Iron and steel can easily be pulled out of a waste stream using magnets, but that doesn’t work with aluminium and magnesium. The latest model of Ford’s famous F-150 truck, which sells in the hundreds of thousands each year, contains far more

aluminium than any previous model. Getting all that metal back out is uneconomic in the US at present.

So ERCo, a company based in Plainfield, New Jersey, is working to adapt a steel recycling technique for use with aluminium. The firm uses lasers to determine the composition of a vat of molten metals derived mainly from aluminium scrap. An automated system then adds more scrap – chosen to turn the mix into a desired alloy.

Gravelly gold

Scrap which contains aluminium is currently crushed and shipped to China, India or Bangladesh, where it is painstakingly sorted by hand. Known as zorba, this gravelly mixture of shredded car seat fabric, aluminium chunks and copper wiring is a human-made gold mine in countries with low labour costs, but shipping it there in the first place wastes energy (see map).

A University of Utah spin-out uses a finely tuned varying magnetic field to do the same sorting without human intervention. Different metals feel the field to different degrees, depending on how it interacts with their atoms. The demo unit I saw running on the ARPA-E conference floor perfectly sorted a conveyor belt feed of copper and brass from aluminium, spitting each metal into its designated container. The firm will trial the technology this year at a plant in Plymouth, Utah, owned by Nucore – the largest steel producer in the US – which generates much of its own raw materials via recycling. Together, these technologies will make for a world that is much lighter on its feet. And just as most of us don’t pay much attention to the steel bridges and beams that surround us, so newly cheap, light metals will start to blend in too. Most of us will get on with business as usual – we’ll just be moving a bit faster. ■

ONE PER CENT



Ro-bird flips in flight

A robo-raven can move each of its flexible wings independently, allowing it to perform acrobatic manoeuvres during flight. Developed by Satyandra Gupta at the University of Maryland, each wing contains an actuator that can be programmed with different positions and velocities. This lets it twist in flight and could be used in UAVs instead of propellers to make them more agile.

“This was our miss, and we will do better in the future”

Chinese laptop maker Lenovo apologises after software that came pre-installed on its laptops was declared a security risk by the US Department of Homeland Security

Countdown to the iCar

Is Apple working on its own electric car? That’s the rumour in Silicon Valley after battery firm A123 Systems LLC, based in Waltham, Massachusetts, filed a lawsuit claiming Apple is trying to poach its employees. Meanwhile, Bloomberg cited unnamed sources saying that Apple intends to begin production of an electric car by 2020 and Tesla boss Elon Musk has claimed that Apple is offering his employees a 60 per cent salary increase to join the firm.

TALENTED TITANIUM

When Napoleon III wowed his guests with pricey aluminium cutlery, those present could hardly have foreseen that a fall in the metal’s cost would usher in an age of air travel and spacecraft. The same goes for the impending light metals revolution.

Sleek cars and fuel efficiency are nice, but what else might ubiquitous light metals unlock? Cheap titanium is particularly promising. With it, we could build structures impervious to creeping salt corrosion, not just on land, but in the ocean too. Replacing

steel with non-corroding titanium could skirt one of the main obstacles to wave power’s adoption.

Titanium could also be used to make wind turbine blades that are easier to spin up. Air travel would become cheaper as planes like the Airbus A380 or the Boeing Dreamliner become standard, not the luxurious long-haul exception. Robots will even get safer as a titanium skeleton carries less momentum, so a moving robot arm is less able to hurt humans.

Watch your city's polluted air in high definition

AND breathe... High-definition cameras are letting residents monitor the air pollution in their cities online, and in real time.

The Breathe Project in Pittsburgh, Pennsylvania, worked with Carnegie Mellon University to create the Breathe Cam – six sensors and four high-resolution cameras that

“The Breathe Cam snaps panoramas at five times the resolution of 4K television”

capture haze and air pollution activity, along with software that visualises the data online. Up and running since December across Pittsburgh, the project equips residents with accurate information so they can lobby more effectively for companies and councils to stick to environmental guidelines.

Developed by the CREATE Lab at Carnegie Mellon's Robotics Institute, the Breathe Cam continuously snaps panoramas at five times the resolution of 4K television.

Residents can log on to one of the cameras and get a current view of the city as well as archived footage going back a year. They can zoom in and see data on fine particles, temperature, sulphur dioxide levels, humidity and wind direction captured by sensors across the city. Users can share the images and data on social media and take snapshots of the air quality to send to officials.

The idea has been so popular that local groups in Pennsylvania are now deploying their own systems. Residents in Allegheny County, for example, are using the software to monitor the local Shenango coke plant and ensure it is complying with regulations.

Roy Harrison at the University of Birmingham, UK, says such systems are great at raising awareness of air pollution. “No hype is necessary, just the facts.” Jonathan Keane ■



STEVE PREZANT/PLAINPICTURE

Right stuff? Just checking

Nothing but the truth

Google is looking at ways to reward the most trustworthy websites

Hal Hodson

THE internet is stuffed with garbage. Anti-vaccination websites make the front page of Google, and fact-free “news” stories spread like wildfire. Google has devised a fix – rank websites according to their truthfulness.

Google's search engine currently uses the number of incoming links to a web page as a proxy for quality, determining where it appears in search results. So pages that many other sites link to are ranked higher. This system has brought us the search engine as we know it today, but the downside is that websites full of misinformation can rise up the rankings, if enough people link to them.

A Google research team is adapting that model to measure the trustworthiness of a page, rather than its reputation across

the web. Instead of counting incoming links, the system – which is not yet live – counts the number of incorrect facts within a page. “A source that has few false facts is considered to be trustworthy,” says the team (arxiv.org/abs/1502.03519v1). The score they compute for each page is its Knowledge-Based Trust score.

The software works by tapping into the Knowledge Vault, the vast store of facts that Google has pulled off the internet. Facts the web unanimously agrees on are considered a reasonable proxy for truth. Web pages that contain contradictory information are bumped down the rankings.

There are already lots of apps that try to help internet users unearth the truth. LazyTruth is a browser extension that skims inboxes to weed out the fake or hoax emails that do the rounds.

Emergent, a project from the Tow Center for Digital Journalism at Columbia University, New York, pulls in rumours from trashy sites, then verifies or rebuts them by cross-referencing to other sources.

LazyTruth developer Matt Stempeck, now the director of civic media at Microsoft New York, wants to develop software that exports the knowledge found in fact-checking services such as Snopes, PolitiFact and FactCheck.org so that everyone has easy access to them. He says tools like LazyTruth are useful online, but challenging the erroneous beliefs underpinning that information is harder. “How do you correct people's misconceptions? People get very defensive,” Stempeck says. “If they're searching for the answer on Google they might be in a much more receptive state.” ■

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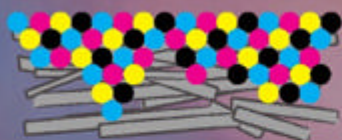


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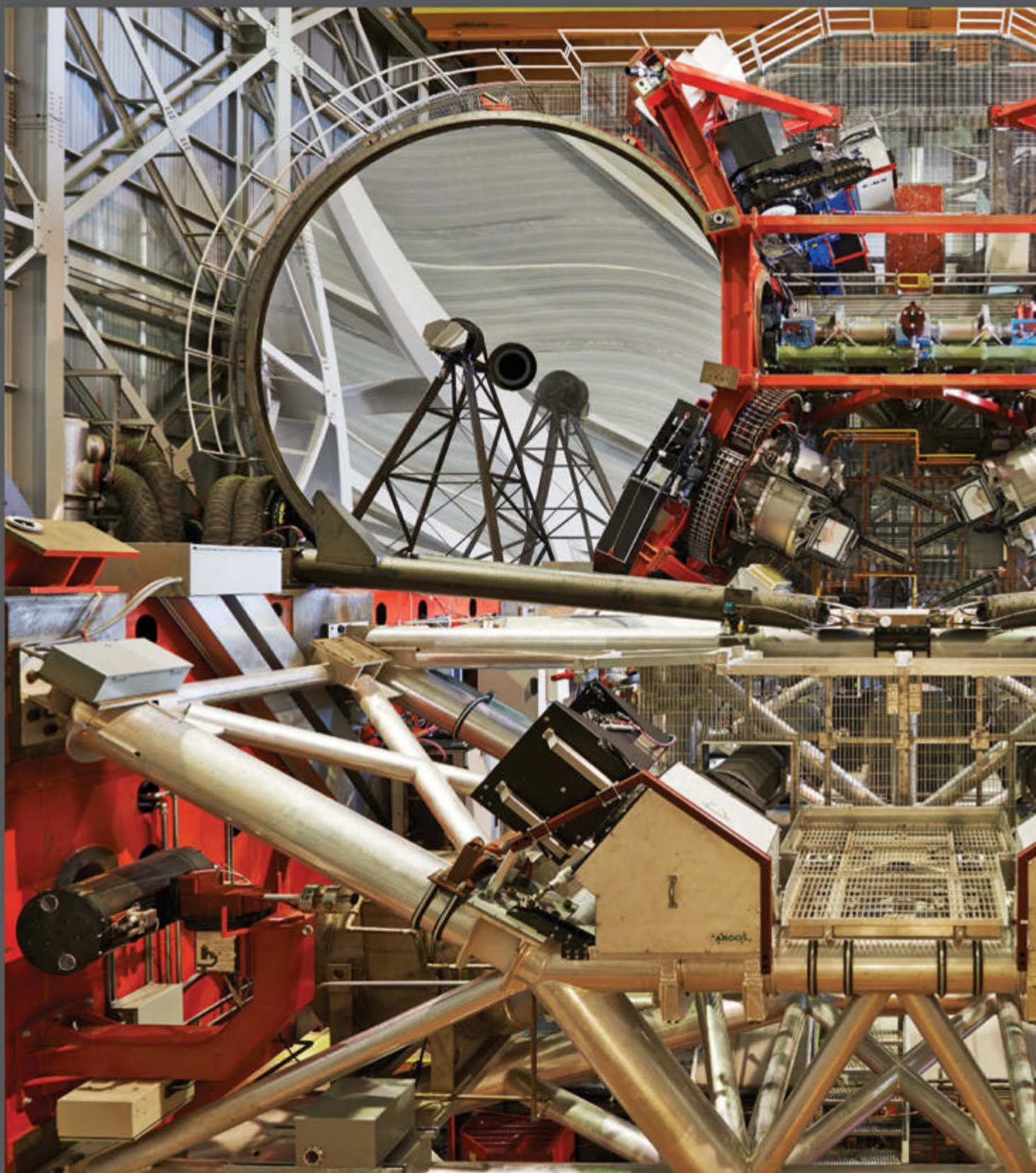


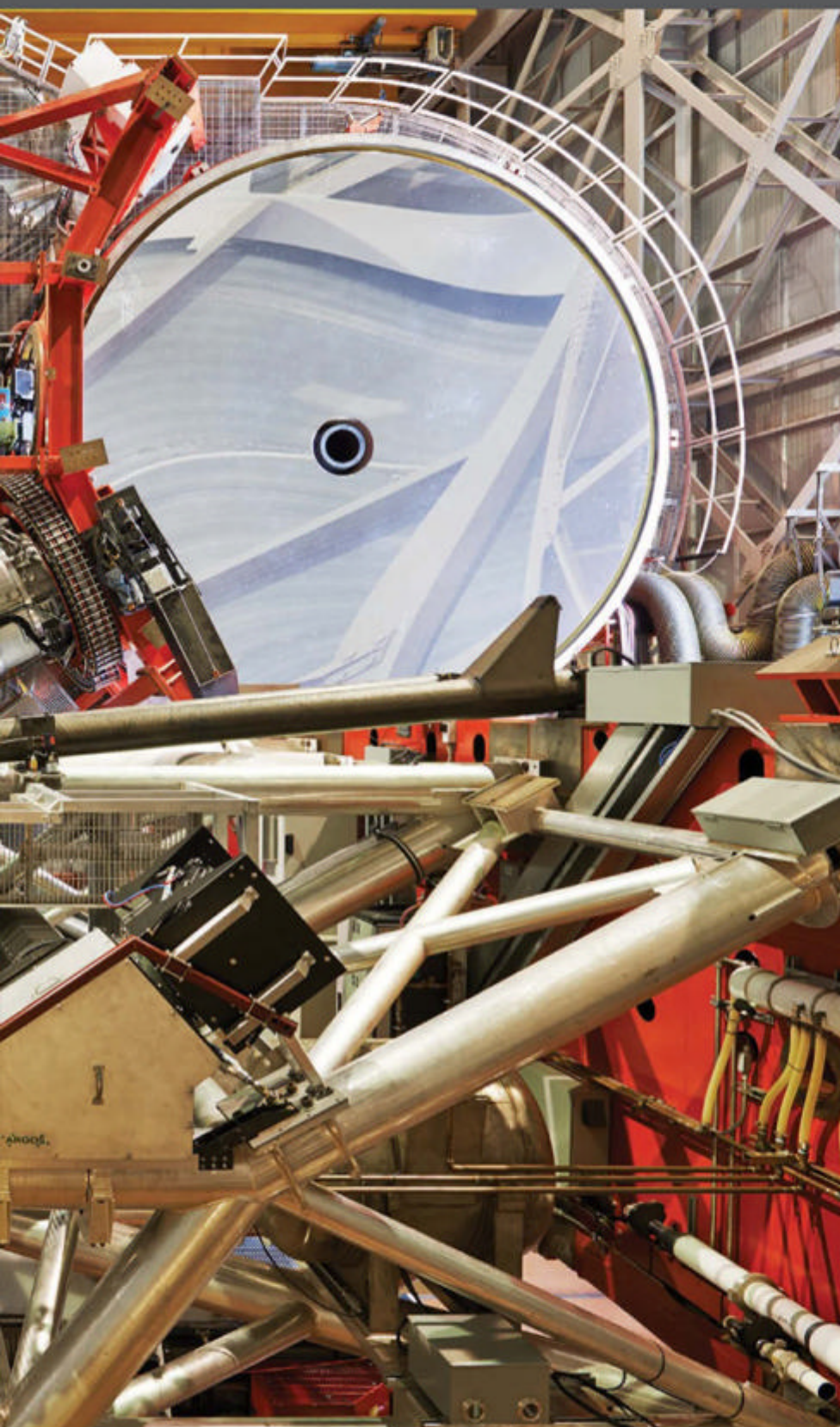
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APERTURE





Robot eyes scan for dust

SORRY to break it to you, but this isn't the head of a giant robot being built in a secret military base somewhere - we don't get pictures of those. Rather, it's a giant pair of eyes staring across vast cosmic distances in an attempt to find aliens. So that's nearly as exciting.

The eyes belong to the recently upgraded Large Binocular Telescope (LBT), which sits on top of Mount Graham in Arizona. Its two 8.4-metre-wide mirrors can collect and combine light as if they were a single 11.8-metre mirror, technically making it the largest operating telescope in the world.

Astronomers are currently using the LBT to study the dust around distant stars, with the hope of understanding how it might obscure light reflected by Earth-like planets in orbit.

Analysing this light could reveal the chemicals present in these planets' atmospheres, potentially hinting at the presence of alien life - but only if we can filter out the effects of the surrounding dust.

It's going to be a good few years before we're able to study these Earth-like planets in such detail. But if hostile aliens happen to come a-knockin' before then, maybe our giant robot head will scare them away. I won't tell them the truth if you don't. Jacob Aron



Photographer

Enrico Sacchetti/INAF
es-photography.com

Green grab, red light

Global intervention in tropical forests to fight climate change could sideline their most effective guardians, warns **Fred Pearce**

SATELLITE images of the Amazon rainforest are startling. Islands of green are surrounded by brown areas of land cleared for farming. In places, the brown advances, year by year. But in others, the forest holds firm. Why the difference? Mostly, the surviving green areas belong to local tribes.

Brazil's Kayapo, for instance, control 10.6 million hectares along the Xingu river in the south-eastern Amazon, an area often called the "arc of deforestation". They held back the invasion that engulfed areas close by, often violently repelling loggers, gold miners, cattle ranchers and soya farmers. The Kayapo have kept deforestation rates "close to zero", according to Daniel Nepstad, a long-time Amazon researcher now at the Earth Innovation Institute in San Francisco.

In these critical frontier zones, the assumption was that government protection could best halt the onslaught. But there is growing evidence that indigenous peoples often provide a stronger bulwark than state decree. The 300 or so indigenous territories created in the Brazilian Amazon since 1980 are now widely held to have played a key role in a dramatic decline in rates of deforestation there.

Similar effects have been documented in many other parts of the world. Forest dwellers are typically seen as forest destroyers. But the opposite is often the case, says David Bray of Florida International University.

Bray has spent a lifetime studying Mexico, where rural communities have long-standing



ownership of 60 per cent of the country's forests, and have logged them for timber to sell. This may sound like a recipe for disaster, yet he says that deforestation rates in community-owned forests have been "generally lower than in regions dominated by protected areas".

One example is in the Yucatan region, where communities outperformed the local Calakmul Biosphere Reserve 200-fold.

Why? Because, Bray says, "communities with rights to resources conserve those resources; communities without rights have no reason to conserve... and deforestation will ensue". Andrew Steer, the head of

the Washington DC-based environment group the World Resources Institute, agrees: "If you want to stop deforestation, give legal rights to communities."

Some environmentalists pay lip service to this new conservation narrative. But too often, forest communities face growing efforts by outsiders to grab their land in the name of conservation.

The latest threat will probably be a global agreement on climate change in Paris later this year, which is expected to formalise a

"Forest communities too often face growing efforts by outsiders to grab land in the name of conservation"

mechanism called Reducing Emissions from Deforestation and Forest Degradation (REDD), already being piloted.

Under REDD, large areas of forests are to be protected as "carbon sinks". It works by allowing those claiming to protect REDD forests to gain carbon "credits", representing the carbon locked up in the forest that would otherwise have been lost to the atmosphere as trees are chopped down or burned. The credits can then be sold to offset industrial emissions elsewhere.

Large areas deemed at risk of deforestation are earmarked for REDD protection in tropical countries as diverse as Indonesia, Cambodia, Colombia, the Democratic Republic of the Congo and the Solomon Islands. It is becoming clearer that forest communities are best placed to do conservation – especially in frontier zones next to heavily degraded forest, where the biggest carbon savings can be made. So you might expect communities to be in the forefront for owning, managing and profiting from REDD schemes. But so far it hasn't turned out that way.

For most, the legal, logistical and scientific barriers are too high. And their governments, sniffing revenues, are not generally supportive of community proposals.

Instead, most pilot REDD projects have been set up by governments with international environment groups and corporations, often in countries with a poor record on land rights for forest communities. Such

projects amount to “green grab”.

A prime example, one of the largest of a series of planned World Bank pilot REDD projects, is in the Democratic Republic of the Congo. Here, according to forest researcher Aili Pyhala of the University of Helsinki, Finland, forest cover is strongly correlated with community control, and the main threat is from government-backed logging and mining. The REDD project is intended to cover 120,000 square kilometres of forest spanning the entire province of Mai-Ndombe – an area almost the size of England.

The World Bank is due to approve the scheme later this year. But most of the 1.8 million local inhabitants haven’t heard about it yet, says Simon Counsell of the Rainforest Foundation UK – even though it threatens their traditional livelihoods of hunting, gathering and forest farming, and ignores their history of successfully managing the forest.

Grabbing such land in the name of conservation risks triggering conflicts that destroy forests. “By conferring new value on forest lands, REDD could create incentives for government and commercial interests to actively deny or passively ignore the rights of indigenous and other forest-dependent communities to access and control forest resources,” warns Frances Seymour, former director of the Center for International Forestry Research.

We are used to thinking of the rights of forest communities and the need to conserve forests as competing imperatives. But the good news is that conservation and human rights can and do go together. To deny forest communities territorial rights is bad for them, but also bad for maintaining the forests.

The benefits of a more people-based approach to conservation could be huge. ■

Fred Pearce is a *New Scientist* consultant. His latest book, *The New Wild* (Beacon Press), is out in April

ONE MINUTE INTERVIEW

Nanohealing at light speed

The body has a habit of scattering medicine to the wrong places. So send in light-activated nanoballs, says **Adah Almutairi**



PROFILE

Materials chemist and engineer Adah Almutairi is director of the Center for Excellence in Nanomedicine and Engineering at the University of California, San Diego, where her team explores novel material properties

What medical challenge does your nano-engineering address?

Biology operates at the nanoscale, so materials designed at that size can respond better to disease. Right now, we have very little control of where, when and how drugs act in the body. We want these processes to work precisely, so that there are no off-target drug effects.

How are you improving drug targeting?

One way is by making materials that respond to inflammation, which underlies lots of major diseases. First we string together molecules called ketals to create polymers, which we build into nanoscale containers that resemble balls of tangled yarn. In trials with mice, we’ve filled these with drug molecules that the spheres release when inflammation flares up, and stop releasing when it subsides.

What size are these balls?

A blood vessel in your thumb is about 1 millimetre across. A single blood cell is about a thousand

times thinner. And finally, our nanoparticle is one-thousandth the size of a blood cell.

How can inflammation trigger drug release?

The start of inflammation involves the build-up of reactive oxygen species and acidic by-products of metabolism. When there’s no acid, the spheres are as stable as a rock, but when they encounter acid, the spheres release their contents.

Can you tell me about the nanospheres you made that open when hit with light?

For those we use a similar release mechanism to that of our inflammation model, but we harness near-infrared light rather than acidity to break open the spheres in exactly the right locations. Near-infrared has a useful mix of properties: it can penetrate tissue while keeping a straight path, so it can be precisely targeted.

Have you tried these on people yet?

Yes, we started with back-of-the-eye diseases. For these conditions you need regular drug injections into your eye. It’s very invasive, and the more injections you have, the greater your risk of scarring and retinal damage. You also need a skilled surgeon: not just anyone can poke you in the eye. So there’s a big need for a single injection that releases therapeutics over time. We began using our nanospheres to encapsulate a small molecule that treats age-related macular degeneration. When you shine light into the eye, you release a dose of the drug. The spheres can stay in place for a year before safely degrading.

How else could these nanospheres be used?

We want to do the same thing with diabetes. So instead of someone with the disease having to stab themselves with insulin when they finish a meal, we want them to be able to just shine light on their abdomen or arm. Another thing is light-activated sunscreen. It wouldn’t do the chemistry to protect your skin when you apply it, but only when you go into the sun. That would be smarter than having to reapply sunscreen willy-nilly.

Interview by Rachel Nuwer

The mother of all problems

Don't blame gluttony or genes for obesity. It's our sedentary habits echoing down the generations, says **Edward Archer**

HOW can skinny people still exist? If we live in an environment that promotes obesity – filled with fast food, sugary drinks, TVs and cars – why isn't everyone obese? And if our genes cause us to be fat, why has the search for “obesity genes” failed?

For me, the quest to answer these questions began when I was a student working in labs with genetically identical mice eating identical food. Surprisingly, the mice differed greatly in size. What caused the differences if it wasn't their diets or DNA?

As I moved between labs, I noticed that pregnant mice without access to exercise wheels produced offspring that would themselves have larger, fatter offspring. While the first and second generations weren't much larger, subsequent generations certainly were. To me, this was an amazing observation: the activity levels of grandmothers and mothers during pregnancy determined the fatness of future generations. But was my observation correct? And if so, what were the mechanisms?

I wasn't the first to observe this trend. Half a century earlier, the geneticist D. S. Falconer had found that by breeding only the largest offspring of genetically identical mice eating identical diets, it was possible to produce progressively larger and fatter offspring over several generations.

This finding supported my intuition that genes and food aren't sufficient explanations of obesity. Despite the recent fanfare over the identification of a suite of genes associated with obesity, they explain less than 2 per cent of the variation in obesity between individuals. This leaves the other 98 per cent – known as the missing heritability – still to be discovered.

When I began my own experiments to find the missing heritability, I found further evidence that calorie intake doesn't explain obesity: active mothers and their leaner offspring ate more food and calories than the fatter inactive mice. Once again, I wasn't the first to discover this. In the 1950s, nutrition scientist Jean Mayer demonstrated that active animals, whether mice, rats or humans, ate more food and stayed leaner and healthier than sedentary ones.

By 2014, I had conducted an extensive literature review that turned my intuition into a theory that revealed the missing heritability and a new way of understanding why so many children today are obese. The answer was a combination of a mother's body composition and physical activity during pregnancy.

When pregnant women are physically active, the increased energy demands redirect nutrients to her muscles and away from her fetus. This competition between the mother's muscles and the developing fetus's fat cells produces leaner, healthier babies. Their genes and food intake are irrelevant to the process.

This competition doesn't happen in inactive mothers. Without having to struggle for energy and nutrients, the fat cells in the fetus increase in both size and number, increasing the birth weight of the infant – a factor strongly related to adult obesity and type II diabetes. This is passed on down the line, with future generations becoming fatter and increasingly inactive and unhealthy.

This is an example of non-genetic evolution, where traits are transmitted to offspring with no underlying change in their genome. This process helps to explain mine and Falconer's

PROFILE

Edward Archer is a physiologist and obesity theorist at the Nutrition and Obesity Research Center, University of Alabama at Birmingham. This essay is based on his paper “The childhood obesity epidemic as a result of nongenetic evolution” (*Mayo Clinic Proceedings*, vol 90, p 77)

What's the real reason behind the childhood obesity epidemic?

observations in mice, while demonstrating the power of the uterine environment to permanently shape the metabolic processes that predispose some fetuses to obesity and metabolic disease.

As it turned out, the idea that the uterine environment affects the fetus is commonplace in evolutionary biology and has been observed across many species. Known as “accumulative maternal effects”, it describes how a mother's age, size, fat stores and behaviour, including physical activity, affect not only her health and metabolism,





predisposing it to obesity and diabetes. However, this doesn't explain why childhood and adult obesity exploded during the late 1970s, when food was abundant. This is where my theory transforms our understanding of childhood obesity.

For most of human history, survival required huge amounts of physical exertion. Hunting, gathering, chopping wood and carrying water provided a dose of physical activity that made deliberate exercise unnecessary. Yet over the past century, socio-environmental changes slowly eliminated physical labour. At first, technological advances coupled with a healthier food supply led to the birth of children that were the fittest in human history. But by the middle of the 20th century, the advent of labour-saving devices, the rising popularity of the car and passive, sedentary entertainment led to people becoming fatter and more inactive.

From 1965 to 2010, the amount of energy

"The search for the genes that make us fat will continue to disappoint"

expended in the home by women in the US decreased by almost 2000 kcal per week. At the same time, the amount of time they spent watching TV and using computers doubled (*PLoS One*, vol 8, e56620). My research has found that obese women in the US get less than one hour of vigorous physical activity per year. Not surprisingly, just as non-exercising mice produce grandchildren that are bigger and fatter, so too do US women.

By the late 1970s, a tipping point was reached in which mothers were so inactive that the evolution of human energy metabolism was markedly altered. As a result, fetuses grew so large that the need for caesarean sections rose significantly. The increased use of surgical interventions during pregnancy allowed both the larger babies and the mothers that produced them to survive and reproduce. Thus, natural selection was rendered artificial selection, and the number of metabolically compromised children and adults increased in the global population.

Non-genetic evolution is the primary determinant of obesity, not gluttony, fast food or genes. The best solution to the obesity epidemic is to encourage would-be mothers to increase their levels of physical activity so that they can prepare their metabolism for pregnancy and have leaner, healthier children. ■

but also that of future generations.

Humans are no exception. For instance, a 1995 study of babies born through egg donation found that the only discernible factor influencing their birth weight was the surrogate mother's body mass. The egg donor's body mass, her own birth weight and the birth weight of her other children bore no relationship to the birth weight of the infant produced from the donated egg (*Early Human Development*, vol 42, p29).

The genes from the egg donor's biological mother played no detectable role in the birth

weight of the infant. This helps to explain why, despite many billions of research dollars, the search for the "genes that make us fat" will continue to disappoint (*Journal of Physiology*, vol 592, p 2381).

The idea that the nine months we spend in the womb affects our health has been around for centuries – it was discussed by the Ancient Greek physician Hippocrates, for example. More recently the "thrifty phenotype" hypothesis developed in the 1990s found that an impoverished uterine environment can programme a fetus's metabolism,

ANDY RICHTER/AURORA PHOTOS



MEYER/TENDANCE FLOUE

The touch that made you

Touching communicates emotions and promotes teamwork
– it may also give us our sense of self,
says Linda Geddes

FIRST bumps and bum slaps, high fives and back pats – most sports teams can't keep their hands off each other. Watch a group of players on a winning streak and you'll see a lot of touching. Keep a tally and it might even give you a way to pick the champions. The teams at the top of the rankings at the end of the US National Basketball Association season, for example, engage in more hands-on interaction from the start than those who ended up at the bottom, according to work by a group at the University of California, Berkeley. Not only does touch seem to signal trust and cooperation, it creates them.

Examples like this are showing that our sense of touch does much more than help us navigate the world at our fingertips. It is becoming clear that touching each other plays a fundamental role in our lives. It isn't just a sentimental human indulgence, says Francis McGlone at Liverpool John Moores University, UK. "It is a biological necessity."

Such touching gives the world an emotional context. It builds trust and promotes teamwork, wins friends and influences people. But that's not all. Beginning in the womb, it may guide the development of regions in our brain that govern social behaviour. It could even give us our sense of self. The touch of others makes us who we are.

Compared to the other senses, however, touch often gets a raw deal. It receives less attention than sight or hearing, say. And yet the skin – our touch detector – is our biggest

organ. An average-sized man has some 5 or 6 kilograms of it – roughly the weight of a bowling ball. As well as regulating our temperature and shielding us from infection and injury, our skin is a communication interface with the outside world. And just as we can lose our sight or hearing, we can go touch-blind (see "Losing touch", below).

The nerves that carry signals from the surface of our skin to the brain run at different speeds. In the fast lane, we have A fibres, heavy duty cables that carry breaking news to the brain in an instant – detailed information that

Losing touch

We can lose our sense of touch in a number of ways. When Ian Waterman was 19, his immune system attacked his nerves and he lost his sense of proprioception – a kind of internal touch that helps us locate our body in space. He could still feel pain and temperature, and his motor nervous system still functioned. But without knowing where his limbs were unless he looked, he couldn't move. It took years of mental retraining to learn how to will his arms and legs into action.

Other cases have been reported in which people lose the ability to feel prods and pokes, with similarly debilitating results. There is also a community of people in Norrbotten, Sweden, who have a genetic condition that makes them largely insensitive to pain.

helps us safely navigate our environment. In the slow lane, however, we have C fibres, thinner wires that deliver messages at a more languid pace. Moving at a sedate 7 kilometres an hour, information carried by one of these nerves takes about a second to travel from a caressed ankle up to the brain.

Our high-speed nervous system is relatively well understood. For years, we also thought the vocabulary of our skin was limited to messages of pressure or vibration, temperature, itches and pain. The slower C fibres were just thought to convey the less immediate components of pain – throbs and aches, rather than pricks, stings and burns. But in the late 1990s, researchers identified a type of C fibre in humans – dubbed C-tactile fibres or CT fibres – that seemed to be activated by soft caresses.

Most touch receptors are concentrated in places like the lips and fingertips. However, CT fibres are found only on hairy skin – almost everywhere except the lips, palms of the hands and soles of the feet – and are concentrated on the top of the head, upper torso, arms and thighs (see diagram, page 37). Like other touch highways, CT fibres are wired up to the brain region that lets us construct a model of the physical world around us – the somatosensory cortex. But they also plug into areas like the insular cortex, which is linked to emotions.

"CT fibres activate this whole network of brain regions involved in thinking about other people and trying to understand what their ➤

intentions might be,” says Kevin Pelphey of Yale University. These same regions also respond to other social cues, such as facial expressions. “We think this touch system is another way to communicate social intentions,” he says.

Or as David Linden – a neuroscientist at Johns Hopkins University in Baltimore, Maryland, and author of new book *Touch* – puts it: fast fibres are all about the facts, slow ones the emotional vibe.

What’s more, they seem to be primed to the touch of others. “These nerve fibres respond optimally to low force, low velocity, stroking movements of around 3 to 5 centimetres per second,” says McGlone. In other words, a gentle stroke. This kind of touch – variously called social, emotional or affective touch – also seems to be activated more by warm temperatures, meaning a touch from cold

“We have as much physical contact within our core relationships as monkeys”

hands is less rewarding. “They are exquisitely tuned to exactly the type of affiliative touching that you see between parents and baby, or between two lovers,” says McGlone.

But what for? It is probably to do with social bonding, if clues from our primate cousins are anything to go by. Robin Dunbar of the University of Oxford and his colleagues at Aalto University in Helsinki, Finland, have preliminary results suggesting that gentle stroking activates similar brain pathways in



humans to those that fire in non-human primates such as rhesus macaques during a grooming session. It also triggers the same release of endorphins. Interestingly, in humans, the density of an individual’s endorphin receptors seems to correspond with the size of their social network.

Since gentle touching is rewarding, Dunbar thinks it encourages individuals to spend time together to develop relationships of trust and obligation. “We probably have as much physical contact within our core relationships as monkeys do within theirs,” he says.

Touch lets us communicate a range of emotions. Gratitude, sympathy and love can all be conveyed with the briefest of touches. “I have always argued that touch is worth a thousand words in terms of understanding how somebody really sees you,” says Dunbar.

Indeed, given our complex social behaviour, the group behind the NBA



basketball study believe touch between individuals may be even more vital to humans than it is for other primates. And it’s almost certainly not limited to sports. “There is nothing special about the NBA,” says Linden. “Social touch is important in developing trust and cooperation in a large number of group activities.”

Touch builds relationships. But it can also be used to fake a relationship where there is none. Salespeople use it to build trust, waiters use it to boost their tips. If you fancy a free bus ride, try touching the driver when you ask.

Emotional touch is hugely influential in our lives, but some think it shapes a lot more than our day-to-day interactions. In fact, touch may be a driver of what makes you you. Studies of the rubber hand illusion in adults suggest that emotional touch plays a role in body ownership, for example. In this experiment, people begin to believe that a rubber hand is their own, if it is stroked and prodded at the same time as their hidden real one. Katerina Fotopoulou at University College London recently showed that the illusion is all the more convincing if the stroking occurs at the speed known to activate CT fibres.

Touch at a distance

Touch is a fundamental part of human communication, but in this era of remote digital interaction are we missing out? Some obviously think so, because there are now devices that can help us connect with colleagues or loved-ones remotely.

One gadget on the market is the Hug Shirt. By donning a sensor-laden sweater, you can record a cuddle by giving yourself a hug. This is then sent to a shirt worn by a recipient, which recreates the strength, duration and shape of your embrace. Other

devices in development include objects that send strokes and squeezes over the internet by making companion devices respond with vibrations and temperature changes.

Can remote touches replace the real thing? Maybe. Michiel Spapé at the Helsinki Institute for Information Technology in Finland and his colleagues recently invited volunteers to play a game of trust called Ultimatum remotely. In the game, two players must decide how to divide a sum

of money. One is asked how the money should be split, the other accepts or rejects the proposal. If an agreement is reached, both players receive their share; if not, neither gets anything.

Being touched by someone often makes us feel more altruistic towards them, so Spapé’s team strapped a vibrating “tactor” to the players’ hands to recreate the sense of being touched. This made it slightly more likely that players would agree when divvying up their spoils.

Setting boundaries

“The psychological sense of being oneself seems to be linked to being touched in this emotional way by another person,” she says. “This may have a crucial role in teaching us the psychological boundaries of our own body, what is mine and what is not.” Fotopoulou also has new results suggesting that people who have had a stroke can recover a lost sense of limb ownership if the arm or leg is stroked on a regular basis.

One question that fascinates many researchers is when this sense of identity develops. It might be that a parent’s touch



Whatever the relationship, touching each other plays a key role in our lives

teaches infants about where they stop and others begin. “We aren’t born with a fully fledged sense of body and self, and so we believe that what parents do is important for building it,” says Fotopoulou.

Our sense of touch kicks in early. It is the first sense to develop, starting about eight weeks after conception, when the fetus is 1.5 centimetres long and brain activity is just beginning. “We know that babies are learning a great deal about touch in the uterus,” says Tiffany Field, director of the Touch Research Institute at the University of Miami School of Medicine in Florida. “They suck on their thumbs, grab the umbilical cord and are constantly bumping against the walls of the mother’s abdomen.”

Emotional touch may also be at work in the womb. McGlone thinks that the swirl of amniotic fluid around the downy, lanugo hairs that cover a fetus may provide crucial

stimulation to a developing brain, guiding the construction of areas such as the insular cortex. For McGlone, such caresses provide a kind of scaffold for the “social” parts of the brain, promoting the growth of synapses and connecting networks in key areas. And this building work continues after birth.

Ongoing stimulation is crucial for the development of other sensory systems, such as vision. If you deliberately block vision in one eye soon after birth, for example, the parts of the brain that process vision from that eye will never develop, even if it is unblocked later on.

“My hunch is that the natural interaction between parents and the infant – that continuous desire to touch, cuddle and handle – is providing the essential inputs that lay the foundations for a well-adjusted social brain,” says McGlone. “It’s more than just nice, it’s absolutely critical.”

McGlone also thinks that these ideas could give new insights into autism, a developmental condition that can affect people’s sensitivity to sensory input. Several recent studies have suggested that some people with autism process touch differently. Pelphrey has evidence that children with autism struggle to process the social significance of touch, for example. “They can feel someone touching them, and the non-social part of their touch system is perfectly active and responsive, but they are not experiencing social touch as different from other types of touch,” he says. “The social significance is not there.”

“Touch is far more primary in early development than most people know or appreciate,” says autism expert Carissa Cascio at Vanderbilt University in Nashville, Tennessee. “Touch is central to the way that

“A parent’s touch teaches infants about where they stop and others begin”

babies interact. Many of the brain changes associated with autism are happening well before verbal speech comes online.”

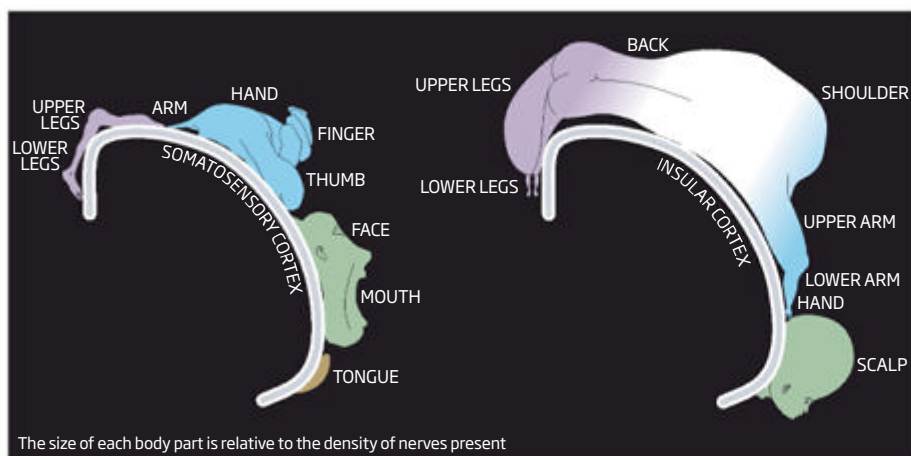
Pelphrey thinks that genetic variation in the system for processing social touch could leave some people more vulnerable if they don’t experience the right sorts of touch in infancy. There could also be a practical side to this research, he says. If the brains of babies who will develop autism do respond differently to gentle touch, this could be used to test for and treat the symptoms of autism spectrum disorders early.

Social touch appears to be far more critical than we thought. Some think we should spin that to our advantage. With the connection between social touching and the brain, for example, perhaps touching could promote performance in the classroom, boost the success of teams and encourage commitment in close relationships. At the same time, however, there seems to be a trend towards less touching in society. Teachers are told to avoid touching children, physical contact is discouraged in the workplace and many of our close relationships are played out online (see “Touch at a distance”, left).

Should we be concerned? “I think we probably ought to be more tactile than we currently are,” says Dunbar. “Or at least we shouldn’t be so frightfully uptight about it.” ■

The internal pleasure map

To the brain’s somatosensory cortex, our hands and face are key when it comes to standard touch (left), but for social touches like stroking, it’s body parts with hair that dominate the emotion-linked insular cortex (right)



The size of each body part is relative to the density of nerves present

SOURCE: JOURNAL OF SEXUAL MEDICINE/SUSANNAH WALKER & FRANCIS MCGLONE, LIVERPOOL JOHN MOORES UNIVERSITY

Linda Geddes is a consultant for *New Scientist*



RON/ZAK ROGERS

Sparks of life

It was single-celled and boring for billions of years, then BOOM! life took off. What caused that dramatic shift? Bob Holmes investigates

THE “tink, tink” of chisel on rock echoes across the valley. High up in the Rocky Mountains of Canada, half a dozen palaeontologists are patiently splitting chunks of shale. Sunburnt, covered in rock dust, with hands blistered from their labours, they have been living rough here near Marble Canyon for four weeks now. The season is short, and they spend almost every daylight hour at the quarry, a rock face about 4 metres deep. But their efforts are paying off.

Before long, a block falls open to reveal an almost perfectly preserved arthropod from half a billion years ago – a distant cousin of today’s insects and crustaceans. Hour after hour, the finds continue – more than 3000 so far. And the richest strata are yet to come. “Starting now, we are expecting an amazing array of new animals,” says Jean-Bernard Caron of the Royal Ontario Museum in Toronto, Canada, who leads the project.

Marble Canyon was discovered just two years ago. It is part of the famous Burgess Shale, perhaps the richest source of information about early animal life on Earth. The tale the shale tells is one of a sudden, dramatic burst of



Excavations at Marble Canyon in Kootenay National Park, Canada, are revealing fossils of animals that lived half a billion years ago, during evolution's equivalent of the Italian Renaissance



BOTH ROM/JEAN-BERNARD CARON

animal diversification known as the Cambrian explosion, evolution's equivalent of the Italian Renaissance. These creatures are so bizarre-looking that 25 years ago, palaeontologist Stephen Jay Gould argued in his book *Wonderful Life* that they represent a failed experiment that left few descendants in today's world. Since then, most of the Burgess fauna have been recognised as members of modern animal groups – albeit odd, experimental ones. That means that in just a few tens of millions of years – a geological instant – almost every major animal group we know made its first appearance in the fossil record, and the ecology of the planet was transformed forever.

The original Burgess Shale in Canada's Yoho National Park was discovered over a century ago, and has yielded some 200 animal species to date. Marble Canyon looks set to surpass even this, and last year Caron's team reported that some of the creatures they found there match those in China's Chengjiang fossil beds, suggesting that some Cambrian species had a worldwide distribution (*Nature Communications*, vol 5, p 3210).

Scientists have struggled to explain what sparked this sudden burst of innovation. Until recently, most efforts tried to find a single trigger, but over the past year or two, a different explanation has begun to emerge. The Cambrian explosion appears to have been life's equivalent of the perfect storm. Instead of one trigger, there was a whole array of them amplifying one another to generate a hotbed of animal evolution the likes of which the world has never seen before or since.

Even without these particularly striking fossils, it is clear that something dramatic happened at the beginning of the Cambrian period, 542 million years ago. For most of the 3 billion years before then, life was unicellular. The first sign of multicellular animals is in rocks about 750 million years old, which contain fossilised biomolecules found today only in sponges. Then another 150 million apparently uneventful years passed before the appearance of the Ediacaran fauna. This enigmatic group of multicellular organisms of uncertain affinities to other lifeforms flourished in the oceans up to the beginning of the Cambrian. Then all hell broke loose.

"Something happened, right at the base of the Cambrian," says Caron. The Ediacarans vanished abruptly, in what may have been the first mass extinction. What took their place is a mystery because we have few whole-animal fossils from the earliest part of this period. But trace fossils – the preserved remnants of burrows, tracks and the like – clearly show that big changes were happening (*Proceedings of the Royal Society, B*, DOI: 10.1098/rspb.2014.0038).

Throughout the Ediacaran period burrows were simple, barely more than shallow trenches ploughed in the seafloor. Palaeontologists can pick out seven distinct types, which they assume correspond to a few different body forms – grazing worms, actively foraging worms, suspension-feeding worms and surface-scratching mollusc-like animals. At the beginning of the Cambrian, that number abruptly jumped to 22.

"In terms of basic forms, you have tripled, very quickly. That is a huge thing," says Gabriela Mangano at the University of Saskatchewan in Saskatoon, Canada. The trace fossils from this time include burrows of all ►

different kinds: deep, vertical, meandering, U-shaped – even burrows that wind back and forth, systematically exploring a patch of ground. At the same time, fragments of fossilised shells, spines and other hard body parts become much more abundant. These indicate that a diverse set of animals evolved early in the Cambrian.

By the time the first whole-body fossils turn up, in shales from about 520 million years ago, almost all the major groups of animals are already present. In other words, virtually all modern groups seem to have originated between about 540 and 520 million years ago. “You go from seemingly nothing to everything in a few million years,” says Kevin Peterson, a molecular palaeobiologist at Dartmouth College in New Hampshire.

Why did this sudden burst of evolution happen when it did? One possibility is it simply took that long for animals to evolve the genetic toolkit necessary to build themselves into complex, mobile forms. “In my mind, 200 million years to figure

So why didn’t the Cambrian explosion happen earlier? If the genetic toolkit was in place, why the lag? “It’s necessary, but not sufficient. It’s not driving,” says Douglas Erwin at the Smithsonian National Museum of Natural History in Washington DC. In other words, other triggers were required. He points to two huge ecological innovations that make their debut in the Cambrian fossil record.

The first is the ability to burrow into the sea floor. These burrows would have broken up the stagnant microbial mats that dominated the Ediacaran sea floor and brought oxygenated water down into the sediment, stimulating productivity. “By ventilating the sediment, you’re basically producing food,” says Erwin. The many kinds of burrows also make for a more complex environment, so that animals have a wider range of ways to make a living.

The second innovation was predation. The beginning of the Cambrian features the first examples in the fossil record of true predators – animals that catch and eat other animals. “I don’t think that’s a coincidence,” says Peterson. With predation comes a much richer and more intense set of evolutionary pressures, as predators and their prey get caught up in “arms races”. This spurs the development of faster-moving animals, hard-bodied prey, stronger predators, better burrowers, sharper sense organs and the like.

Taken together, these probably led to an evolutionary snowball effect, as one original design begat another and diversity begat greater diversity – leading, within a few million years, to the profusion of new body plans and lifestyles evident in Caron’s Marble Canyon fossils. In effect, the rapidly evolving animals of the Cambrian were inventing whole ecologies on the fly, says Erwin.

Such a burst of creativity would be unlikely in today’s world, which is already teeming with animals of all sorts and sizes. But the ecologically sparse Cambrian world would have presented less competition, allowing animals to work out the “growing pains” that are inevitable with any radical redesign. Erwin points out that you see similar evolutionary experimentation after mass extinctions. For example, the great Permian extinction 252 million years ago, in which over 90 per cent of all species became extinct, was followed by



a spate of innovation in vertebrate form that led to the dinosaurs, turtles and others.

This case for an ecological trigger has been around for several years, but it still doesn’t explain the exact timing of the animal explosion. What sparked the key innovations that were needed for a biological boom? What else were these early creatures waiting for?

Fantastic fertiliser

One intriguing possibility is that they were waiting for fertiliser. Geological evidence suggests that rising sea levels during the Cambrian could have increased erosion, boosting levels of nutrients such as calcium, phosphate and potassium in the oceans. This fertilisation would have sparked an increase in productivity, providing more resources, generating longer, more intricate food chains and allowing the ecological positive feedbacks to take off. But there’s a problem with this idea. “Nutrients alone don’t tell you how you get increases in ecological complexity and diversity,” says Erwin. “If you put nutrients into an ecosystem today, what you get is a huge increase in abundance of a small

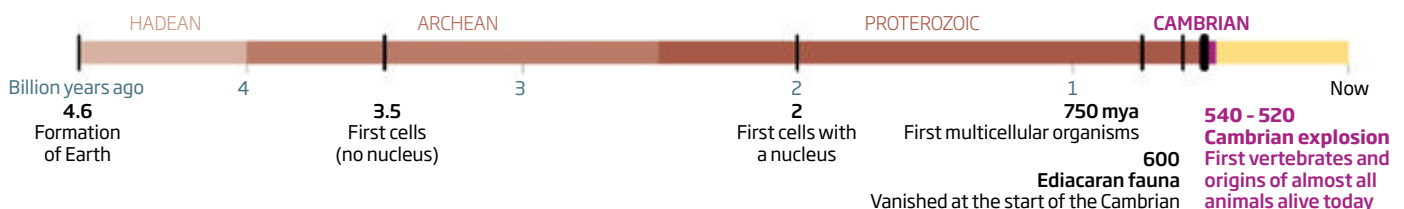
“Like any good mystery, the Cambrian explosion has several key suspects”

out all the body plans and get things going seems about right,” says Nick Butterfield, a palaeontologist at the University of Cambridge. He describes the gene networks that control development from an egg into a multicellular animal as the most complex algorithms ever developed. “At some stage, everything’s going to line up and take off. I call that the Cambrian explosion.”

But that explanation may be too simple. Studies of “molecular clocks” – which use the gradual accumulation of genetic changes to estimate when particular evolutionary branches diverged – suggest that animal complexity emerged before the Cambrian (*Science*, vol 334, p 1091). For example, humans and starfish have a common ancestor back in the Ediacaran period, implying that the shared details of their biology – including body cavities, guts, nervous systems and more – must have been present then, too. “Developmentally, everything’s there long before the Cambrian,” says Peterson.

Life’s long fuse

For almost as long as the planet has existed, there’s been some kind of life on Earth. Yet it stayed much the same for 3 billion years before suddenly exploding into variety. Why?





ROM/JEAN-BERNARD CARON



BOTH ROM/JEAN-BERNARD CARON

Marble Canyon has yielded some 80 animal species in two years, including sponges (top) and arthropods (below). Bottom: the Marble Canyon camp

number of species." Today's polar oceans, for example, are among the most productive and least diverse marine ecosystems.

Nevertheless, calcium was key for one Cambrian innovation: high levels dissolved in the oceans, combined with carbonate ions, would have made it easier for animals to form hard shells and skeletons, helping spark the ecological arms race. In fact, these high calcium levels might even be the reason the Burgess Shale fossils are so well preserved. But most species that appear in the Cambrian explosion are entirely soft-bodied. "What about the rest of the animals?" says Caron. Some further ingredient is needed.

One likely candidate is oxygen. For most of Earth's history, oxygen gas was exceedingly rare. A study published in October concluded

that until 800 million years ago, oxygen levels were less than 0.1 per cent of present levels, which would have precluded any sort of active animal life (*Science*, vol 346, p 635). Atmospheric oxygen levels crept up gradually after that. And although geochemists do not yet agree on the specifics, at some stage oxygen levels in the oceans would have risen to the point where active, predatory lifestyles became possible.

To learn more about where this point was, Erik Sperling at Harvard University and his colleagues looked to modern sea floor habitats. Sure enough, sites that were almost devoid of oxygen had very few predators, while those with more oxygen supported more diverse communities of predators, they reported in 2013 (*PNAS*, vol 110, p 13446). The crucial

threshold seemed to be between 1 and 5 per cent of present oxygen levels. Geochemists' best guess at when the ancient oceans reached this point is about 550 million years ago – just in time to kick off predation and its resulting ecological feedback. "That's about what you'd expect if oxygenation was a trigger for the Cambrian explosion," says Sperling.

Most biologists think that photosynthetic plankton were responsible for the gradual increase in oxygen. Last year, however, a few researchers argued that animals may have had a hand in fashioning the trigger, too (*Nature Geoscience*, vol 7, p 257). The idea, proposed by Butterfield, goes like this: Precambrian oceans were full of single-celled algae and bacteria. When these small cells died, they would have started to sink, decomposing quickly as they went – and because decomposition consumes oxygen, this would have kept ocean waters anoxic. Filter-feeding sponges, which evolved sometime before the Ediacaran, then started clearing these cells out of the water column before they died and decomposed. The sponges themselves, being larger, were more likely to be buried in the sediment after death, allowing oxygen to remain in the water. Over time, this would have led ever more of the ocean to become oxygenated. "The sponges basically march from shallower to deeper water, oxygenating as they go," says Erwin.

Like any good mystery, the Cambrian explosion has several prominent suspects. It is becoming increasingly clear that they worked together, but we still don't know exactly how. "It's very difficult to separate what are the triggers and what are the consequences," says Caron. Nevertheless, as palaeontologists find more fossils, and develop more techniques for inferring past environments from geological clues, the answers may emerge quickly. "There are so many really good people working on this," says Erwin. "It's amazing how fast things are changing."

Caron and his team at Marble Canyon are in the vanguard of this progress. In just two short excavation seasons they have found thousands of fossils from some 80 species, 10 to 15 of them never seen before. Their finds will shed more light on the perfect storm of factors behind the Cambrian explosion, but Caron still can't resist wondering what sparked the storm. "I think that's the million-dollar question," he says. And occasionally he worries there may be no way of knowing. "It's possible that what we're looking at here is a random event." ■



ROM/ZAK ROGERS

Bob Holmes is a consultant for *New Scientist*

Build your own

You may never get to work at a world-famous physics lab, but you can recreate cutting-edge experiments at home, says **Jon Cartwright**

JAMIE EDWARDS is every bit the nuclear scientist – curious, diligent and passionate about unlocking the energy stored inside atoms. Last year, having scoured the web for parts and blueprints, he built his first working fusion reactor. The project would have been a tremendous feat for anyone, but in Jamie's case there was an additional wow factor: he was just 13.

Jamie found himself propelled to global stardom by his achievement. The media were abuzz with excitement that the same process that makes the sun shine had been harnessed in Penwortham, a small town in northern England. The US television host David Letterman invited Jamie on to his chat show to discuss what prompted him to set about fusing hydrogen nuclei in a school laboratory. "I guess it was just the curiosity – I found it fascinating," says Jamie, who has also been invited to talk about fusion to scientists several times his age.

Fusion probably brings to mind huge experimental facilities, such as the \$50 billion International Thermonuclear Experimental Reactor under construction in the south of France. ITER aims to become the first fusion reactor to generate more power than it consumes when it crams together heavy hydrogen nuclei at temperatures of millions of degrees.

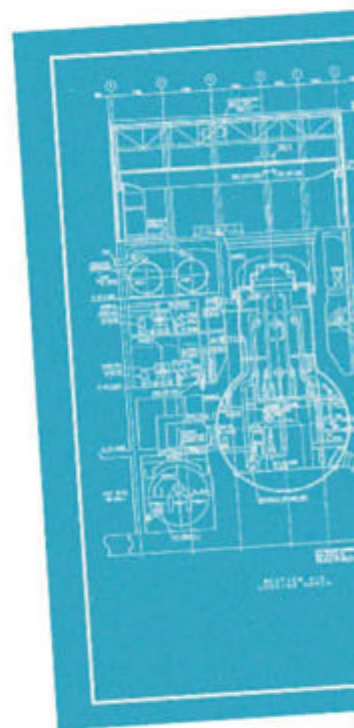
Yet Jamie has shown that modern physics does not have to be the preserve of an international multibillion-dollar facility. His fusion reactor melded together nuclei of

deuterium, an isotope of hydrogen with one neutron, inside an evacuated chamber with a high-voltage power supply. Jamie's simple approach is not one that will ever generate useful energy. Yet his success is no less gratifying to anyone with an interest in science.

It turns out that a fusion reactor is not the only physics apparatus of recent times that you can knock together yourself – to a crude approximation, at least – using readily available materials. Want to mimic experiments that search for dark matter? A dismantled fire extinguisher could do the job. How about a scaled-down version of a gravitational-wave detector many kilometres long? No sweat, if you first get yourself a laser pointer. What you may lack in knowledge, experience and international backing, you can make up for with a can-do attitude. "It was quite hard," says Jamie of his fusion project. "My science teachers didn't have a clue... But after a bit of research, a bit of beg, steal and borrow, I eventually got there."

What few appreciate about this sort of home-made physics is that real scientists are at it, too. Todd Johnson, a physicist at Fermilab in Batavia, Illinois, has used his spare time to invent – among other things – a tornado generator, a nighttime bat detector and a miniature particle accelerator.

Go on, then: experiment with some truly wonderful do-it-yourself lab gear. It might just bring out your inner 13-year-old. ➤





JAM JAR DETECTOR

There is a monstrous gulf between general relativity – which deals with the very big – and quantum mechanics – the theory of the very small. How to reconcile the two? Various theories are on the table, from quantum gravity to string theory, yet we are largely in the dark as to which option is right. One way to open a small experimental window on this area is to exploit the phenomenon of time-reversal symmetry. In the subatomic world, if you were to film two electrons bouncing off each other, the physics would be the same whether you ran the movie forwards or backwards. “Whatever the next step in physics, it will need certain features that break time-reversal symmetry,” says Tim Chupp at the University of Michigan in Ann Arbor.

Chupp is trying to test whether time-reversal symmetry exists on the smallest scales using atoms, which behave just like tiny spinning bar magnets when they are placed in electric and magnetic fields. If time-reversal symmetry is violated, the atoms ought to spin faster or slower when the electric field is flipped. To measure the spin frequency, Chupp makes use of a device called an optical magnetometer, which shines a laser on the atoms to track changes in how fast they spin.

To stand a chance of glimpsing a violation of time-reversal symmetry, Chupp’s magnetometer has to be extraordinarily precise – no surprise, then, that it costs thousands of dollars. Having said that, an inexpensive home-made magnetometer might perform much better than you expect. According to amateur scientist Robert Cobain in Bangor, UK, making one is not much more difficult than suspending a neodymium magnet – from a pair of headphones, for example – inside a jam jar with a small mirror (bit.ly/1CvBkVh).

When a laser pointer is directed at the mirror, any small rotation by the magnet will be amplified as a much bigger movement of the laser’s dot, reflected on to a nearby wall. The set-up is sensitive enough to reveal fluctuations in the Earth’s magnetic field, which also behaves like a bar magnet. These fluctuations are most obvious during geomagnetic storms. Some more mundane phenomena also come to light, as Cobain writes in his blog. “This magnetometer will go crazy if someone downstairs sets up an ironing board, or if a car drives near your house.”

DUST-SIZED DISTURBANCES

In terms of precision, a magnetometer is nothing compared with the Laser Interferometer Gravitational-Wave Observatory in the US. LIGO’s laser beams, each 4 kilometres long, are so well aligned that a movement just 1-billionth the size of an atom will show up as a change in the pattern they make. “They’re the most sensitive instruments on the planet,” says Fred Raab, the head of LIGO’s Hanford Observatory in Richland, Washington.

LIGO needs such sensitivity to search for gravitational waves, subtle swells in space-time predicted by Einstein’s general theory of relativity. But Raab says you can still reach a surprising level of sensitivity with a home-made interferometer – measuring shifts down to at least a micrometre, or the size of a speck of dust.

Your shopping list should include a laser pointer, a couple of coin-sized mirrors, a beam splitter and a lens, all of which can be bought for \$50 or less online. If you arrange the components correctly, the laser beam will split into two perpendicular paths before recombining into a ringed interference pattern. Helpfully, the LIGO website provides instructions on setting things up (bit.ly/1DFY0zf).

The interferometer will be exceptionally good at picking up vibrations. Attach a piece of string to it, says Raab, and just stroking it lightly will cause the interference pattern to grow and shrink. If you make a cup of coffee, watch out: the merest waft of hot air could make the components expand enough to change the pattern.



What you lack in experience and international backing, you can make up for with a can-do attitude



BUBBLE TRACKERS

Roughly 2 kilometres underground at Sudbury in Canada lies a 60-litre vat of trifluoromethyl iodide, a chemical used in fire extinguishers. It is heated until teetering on becoming a gas, so that the slightest disturbance – specifically, a charged particle passing through – results in a pretty string of bubbles where the liquid has vaporised. Such bubble chambers can reveal the tracks of all sorts of radiation, but the one beneath Sudbury, known as COUPP, is geared up to detect dark matter – a substance thought to be almost everywhere, yet never glimpsed so far.

Although COUPP is one of the most sensitive experiments of its kind, it hasn't yet come across any bubbles that look like dark-matter trails. In any case, says Juan Collar, who helped design COUPP, it is fascinating to watch. "Bubble chambers allow you to see radiation before your very eyes," he says. "You could spend hours looking at one."

Collar likes bubble chambers so much that he is building a small one himself. Like Jamie Edwards, he has bought many parts on eBay for peanuts. The apparatus does not have to be complicated, he says, although you do need a microphone that listens for the telltale "plink" of fleeting bubbles and then triggers a camera to photograph them before they disappear. Collar achieves that by connecting the two devices via an inexpensive Arduino microcontroller, popular among electronics hobbyists.

As for a suitable liquid, you could take a fire extinguisher apart – although you'd have to be reckless to try. Alternatively, follow the example set by the inventor of the bubble chamber, the Nobel-prizewinning Donald Glaser, and try something rather more frothy instead: beer.

READING BETWEEN THE LINES

OK, being developed in the early 19th century, spectroscopes are about as modern as steamboats. Yet they are integral to modern astrophysics: some of the field's best-known recent discoveries would have been impossible without them, like exoplanets, water on Mars, dark energy... the list goes on.

A spectroscope splits light into its component colours, telling you what the light-source is made of, or how it is moving. Simon Quellen Field, the author of *Gonzo Gizmos: Projects and devices to channel your inner geek*, describes how to make one using a DVD as a simple diffraction grating. You mount the disc inside a cardboard box, cut a slit to let light in and insert a toilet roll as a viewing port. The rainbow of coloured lines you see diffracted off the DVD (bit.ly/1iNNT3J) will depend on what you aim the spectroscope at.

The cardboard spectroscope can't perform proper astrophysical measurements to determine redshift or atmospheric composition. But Field says that by splashing out on a holographic diffraction grating, which can be bought for a few dollars online, some "real science" will be yours for the taking (bit.ly/1DuxlZw). "You can tell which gases are in neon signs, or if that green stain is chlorophyll or food colouring," he says.

SALAD-BOWL ACCELERATOR

It can be difficult to comprehend how big and complex the Large Hadron Collider (LHC) really is. CERN's flagship accelerator has a ring 27 kilometres in circumference straddling the border between France and Switzerland. It fires protons or lead ions to within a fraction of the speed of light, steering them with nearly 10,000 superconducting magnets that are colder than outer space. How could you ever emulate such a facility?

Todd Johnson, based at CERN's rival Fermilab, likes to use a salad bowl. Granted, his particle accelerator will not churn out any Higgs bosons, but it is somewhat cheaper and easier to build than the \$9 billion LHC. And it will at least demonstrate the basic workings of one of the world's biggest experimental facilities.

To make your miniature LHC, says Johnson, begin by gluing strips of foil to your salad bowl so that they fan out from the centre. Connect every other strip to one terminal of a high-voltage power supply – which you can either buy or pull from an old electric air purifier – and the remaining strips to the other terminal. Then coat a ping-pong ball with conductive paint, and drop it into the centre. The nearest foil electrode will attract the ball until it touches, acquiring the same polarity. However, the ball will then be repelled, only to be attracted to the next electrode along, which has the opposite polarity. When the ball touches it, it is once again repelled and drawn to the neighbouring electrode. Slowly but surely the ball will go round the bowl, accelerating until it is whizzing round almost faster than you can watch (bit.ly/1zKRB6H).

Unfortunately, air resistance limits the ball's top speed, but Johnson can think of a way round that. "One can imagine evacuating the hemisphere," he says. Of course, that's the trouble with science: once you start experimenting, you'll never stop. ■

Jon Cartwright is a journalist in Bristol, UK

Planning to do a quick physics experiment in your basement? We want to see it in action! Tweet us your original and eye-catching creations, either as a video or animated gif, using #NSHomePhysics as the hashtag. Our favourites will be featured on newscientist.com, so stay tuned...



THE GREAT INVASION

Aliens have been pouring into the Mediterranean Sea through the Suez Canal for decades, and it's about to get a lot worse, reports Tom Ireland

IN 2011, workers struggled to unclog the cooling system of a power plant in Hadera, Israel. Thousands of what looked like wet plastic bags were desperately scraped out of the plant's water intake. But still they kept pouring in – breaking up into gelatinous slime and threatening to cut off the electricity supply of millions of people.

The culprit was a large stinging jellyfish called *Rhopilema nomadica*. It often forms massive swarms, some as much as 100 kilometres long. “When these blooms appear, tourists have to stay on the beach, and fishermen have to stay on the shore,” says marine biologist Bella Galil of the National Institute of Oceanography in Israel.

Yet until the mid-1970s, this species wasn't found in the Mediterranean. It arrived via the Suez Canal. For most of the year, the current in the canal flows from the Red Sea northwards in the direction of the slightly lower Mediterranean. “It's like one of those travelators at the airport,” says Galil. “You get on it and whoosh, you're in the Mediterranean.”

As a result, hundreds of species from the Red Sea have invaded the Mediterranean. And things are about to get even worse: the invader travelator is getting an upgrade. Last year, Egypt announced a \$4 billion project to widen the existing canal and add another lane, doubling its capacity by the end of 2015, to the alarm of biologists. But this doesn't have to be bad news, they say: the canal can

be expanded and the flow of invaders slashed at the same time.

Invasive marine species can arrive by many routes, from hitching a ride in the ballast water of ships to being released from aquariums. But the 190-kilometre-long Suez Canal is undoubtedly the main invasion route into the Mediterranean. In a study last year, Galil estimated that of the 700 or so invasive species recorded in the Mediterranean, half had arrived via the Suez Canal. A separate 2014 study put the number of invaders at 1000, with 420 coming via the canal.

Med turning Red

To put this in perspective, there are about 17,000 species in the Mediterranean, of which 1000 are found only in that sea. So the number of invasive species could soon outstrip the number of endemic species, if it hasn't already. “Bioinvasions occur all over the world. But here it is much worse,” says Galil. “Now we are facing a doubling of that system.”

Global warming is aiding the invaders, too, by making it easier for tropical Red Sea species to survive in the cooler Mediterranean. “The Mediterranean is warming, meaning it is becoming much more hospitable to invasive Red Sea species,” says Galil. “The practical border of the Red Sea is now somewhere off the coast of Italy – Sicily, Malta, even as far as Gibraltar.”

Does it matter? The invasion isn't all bad

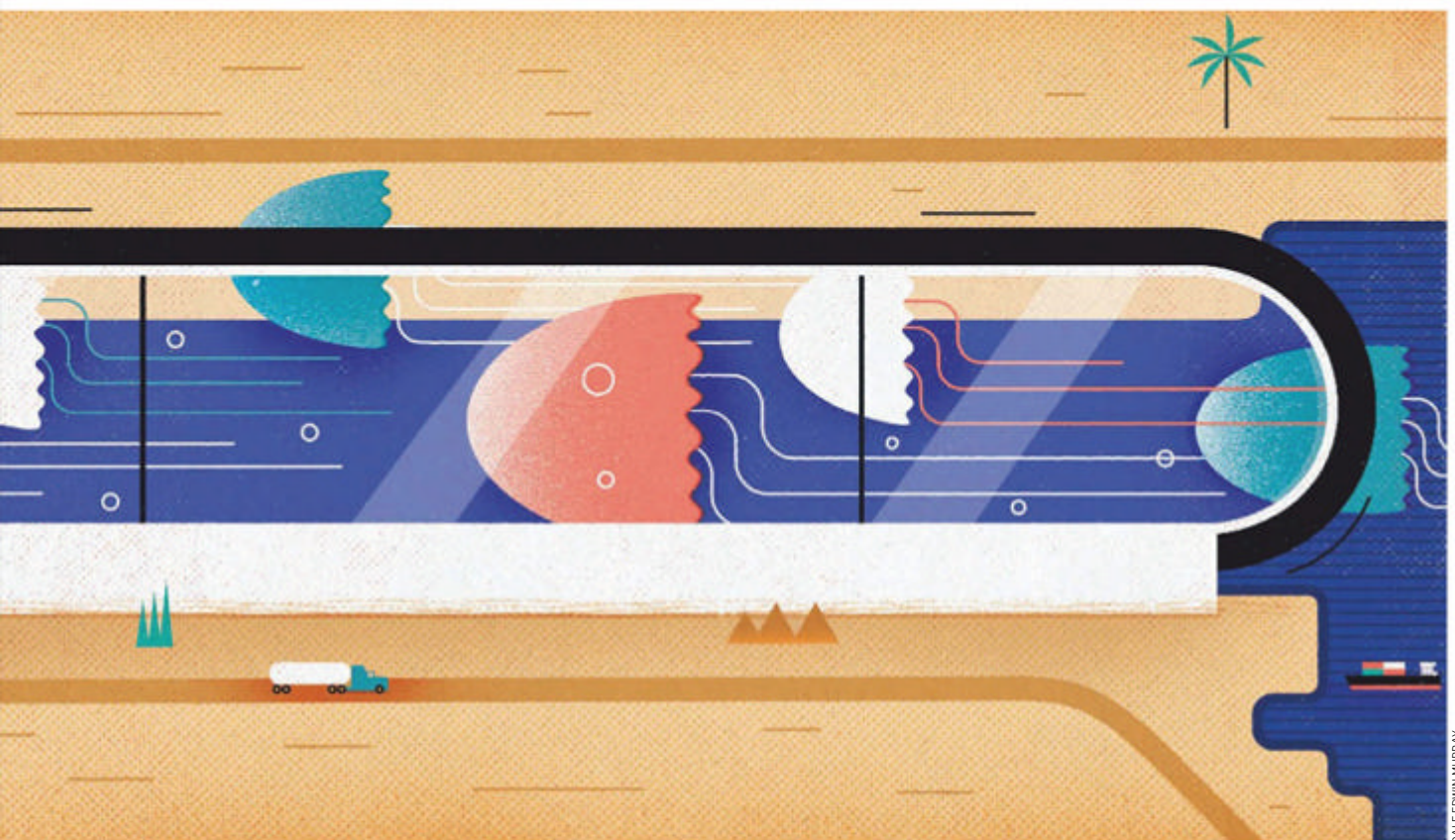
news. There are some benefits for the fishing industry: the soaring populations of some invasive species have increased catches in some places, and the large Japanese tiger prawn is particularly prized. The invaders are also increasing biodiversity at a time when it is declining almost everywhere else in the world, says Daniel Golani, a biologist at the Hebrew University of Jerusalem.

But some of the newcomers are outcompeting and displacing native species, not increasing diversity by living alongside them. And others are making a nuisance of themselves. The *R. nomadica* jellyfish costs the fishing industry dear. During swarms, it is not unusual for boats to have to discard their entire catch because their nets become clogged with jellyfish. “It's not good news economically,” says Galil.

What's more, at least 13 people have died and dozens more have been hospitalised after eating the toxic silver-cheeked pufferfish, *Lagocephalus sceleratus*, another Suez migrant which has spread across the eastern Mediterranean over the past decade. People were initially unaware of the danger.

Golani argues that it is subjective to say invading species “damage” ecosystems. But in at least some cases, the term damage seems justified. Take the two species of Red Sea rabbitfish, first recorded in the eastern Mediterranean in 1924. In the warm regions where these fish thrive, there has been a fall of 65 per cent in the abundance of large seaweed





Red spread

Red Sea aliens are found across the Mediterranean

Number of invasive species found in an area of 10 × 10 kilometres

● 1-7 ● 8-26 ● 27-50 ● 51-85 ● 86-128



and 40 per cent in overall species richness, a 2014 survey found. The problem, it concluded, is that while native herbivores eat only adult seaweed, the invading rabbitfish nibble at the rocks too, eating very young seaweed and preventing regeneration of the seaweed forests that many other species depend on.

The overall impact of this massive bioinvasion into the Mediterranean is poorly understood, though. Much of the sea isn't well monitored, so we don't know what's happening. It's also hard to disentangle the effects of invaders from those of pollution, overfishing and climate change.

What's more, it will be many decades, or even centuries, before the full impact of existing invaders becomes clear. Many invasive species do not seem to be a problem at first, only to start running riot after a few decades, perhaps because it takes them time to adapt to local conditions. And invasion via the Suez only began in earnest in the 1970s.

When the canal opened in 1869, large salty lakes along its path and freshwater from the neighbouring Nile acted as natural barriers. The sudden changes in salinity killed most organisms as they were travelling through.

But by the 1970s the salt deposits in the lakes were washed away by the ever-widening waterway and the fresh water was cut off by the damming of the Nile.

In a letter published last year, Galil and signatories representing 14 marine biology organisations called on the Egyptian government to prevent even more invaders arriving, arguing that “the potential reach and magnitude of the cumulative impacts are enormous”. The number of signatories has grown to 278 scientists from 33 countries.

They say reintroducing salinity barriers by installing locks could be a way of mitigating the impact of the canal expansion. “We are not against the development of the Suez Canal,” says Galil. “That is important to stress. We just want it to be done in an environmentally sensitive way.”

Neither the Egyptian government nor the Suez Canal Authority responded to *New Scientist's* requests for comment. Even the UN's Mediterranean Action Plan, an organisation tasked with protecting the sea, admits it is only now contacting the Egyptian authorities about whether the canal expansion will contravene the Barcelona Convention – an agreement to minimise pollution and species invasions in the Med.

In the meantime, the invasion continues. ■

Tom Ireland is the managing editor of *The Biologist* at the Society of Biology



When the cows went mad

The ghastly spectre of BSE has returned – this time in a challenging exhibition. **Andy Coghlan** revisits the tale

History Is Now: 7 artists take on Britain, the Hayward Gallery, London, until 26 April 2015

“YES, of course, I ate loads of burgers,” laughs Roger Hiorns.

Hiorns is one of seven contemporary British artists curating *History Is Now*, an exhibition timed to coincide with the run-up to the UK general election in May. His contribution reprises one of the darkest sagas in the history of agriculture: the rise

and fall of mad cow disease, or BSE.

The Hayward Gallery asked each of the seven to chart the evolution of specific strands of the UK’s social history since the second world war. Topics picked by the other six artists include the development and influence of cinema, the impact of protest and the growth of consumerism as a measure of well-being.

Hiorns’s theme is the one that most firmly embraces science. And his admission that he ate lots

of beef between 1980 and 2000, when it was considered a highly risky business in the UK, adds a personal touch to his artistic contribution.

There he reveals meticulously, and engagingly, the trajectory of BSE. For me, it was like zooming back in time, revisiting in one manic flurry the multitude of twists and turns in the tale I covered for *New Scientist*.

By 1996, there was confirmation that the disease had jumped over

into humans, causing variant Creutzfeldt-Jakob Disease (vCJD), the harrowing equivalent of mad cow disease. To date, 177 UK citizens have died, with 52 deaths recorded in other countries, half of them in France.

Can we expect more cases of vCJD in Britons who, for 20 years, consumed beef potentially infected with prions? The mutated brain protein can destroy the central nervous system and brain, leaving it a spongy mass of holes, characteristic of BSE.

So far, as Hiorns points out, all the people who have died, except one, have had just one of the three possible genetic profiles that may affect their vulnerability to the disease, and almost all succumbed at an incredibly young age, typically between the late teens and late 20s.

But 60 per cent of the UK population has one or other of the other two genetic variants. Could they too be infected, but not succumb until later in life? "This thing may not be over yet," says Hiorns.

Whether it is or not, the exhibition is a masterpiece of historical, fact-based presentation, and a timely reminder of a crisis that gripped the UK, and later much of Europe, for two decades. "It's a terrifying subject that created a sense of dread in our generation," says Hiorns.

Aided by some stunning artworks and artefacts, including cows' heads preserved in formaldehyde by the British artist Damien Hirst, and a 3D model of the prion protein, Hiorns set out to deliver what he calls "a slice of truth", a warts-and-all account of what happened from the start of the crisis to its finish.

As his exhibition shows, the saga severely undermined public faith in the ability and will of politicians to protect them from harm, and revealed the extent to which the interests of farmers, butchers and food retailers overrode those of ordinary people.

BSE showed up for the first time in 1984. As early as 1987, scientists had worked out that animal carcasses turned into cattle feed were spreading the contagion.

The government banned the feeding of animal protein to cows in June 1988, although this didn't stop the epidemic. BSE peaked in 1992, when there were 37,280 cases.

Few suspected that the disease would cross into people, but in 1989, as a precaution, the government banned cow tissues most likely to harbour prions from reaching the human food

chain. These included offal, brains, spinal-cord material, the spleen and the intestines. This move alone may have saved millions of lives.

But beef remained on sale. Hiorns's exhibition includes footage of the now-famous incident in 1990 when the UK agriculture minister, John Gummer, tried to convince the public that beef was safe by unsuccessfully attempting to get his daughter Cordelia to take

"The BSE saga severely undermined faith in the ability and will of politicians to protect us"

a bite of his burger. That, Hiorns believes, was the turning point, the moment when the public lost faith in the government stance.

As the BSE epidemic ploughed on through its peak, the government stuck fervently to its line that the disease couldn't cross over into people, even after reports of unusual deaths in farmers beginning as early as 1993.

The dam finally broke in 1996, when scientists demonstrated that a handful of young people had died from a new disease that

was unequivocally the human equivalent of BSE. One of Hiorns's major exhibits is the "western blot" test of human brain proteins, produced in May 1996 by John Collinge of University College London. It proved that BSE and vCJD were the same disease. "For me, it's the icon of the show," says Hiorns.

On 20 March 1996, UK health secretary Stephen Dorrell announced a "probable link" between BSE and vCJD. The news traumatised the nation. A week later, there was a global ban on British beef exports, and "mechanically recovered meat" was excluded from the UK food chain. This concoction of meat fragments, obtained by the high-pressure spraying of carcasses, was suspected of carrying prions from infected animals. New fears surfaced that vCJD could spread in incompletely sterilised surgical equipment, or in blood donations.

In 2000, the results of a two-year inquiry into the whole saga were finally published. By this time, BSE had spread to Europe, and by 2003 it reached the US.

This 1982 portrait of Andy Warhol now leaves a strange aftertaste



Epidemiologists predicted that "thousands would die" of vCJD, a finding they based on prions detected in appendixes at post-mortems.

The sense of panic, ably captured in Hiorns's choice of news cuttings, video footage, official documents and artefacts, lasted for at least another four to five years until the BSE epidemic began to peter out – and then almost vanish globally. But not completely: Canada reported a case on 18 February, and Norway one last month. The doomsday scenarios of mass dementia, however, didn't materialise, and the visceral impact of the saga began to fade.

Hiorns expresses great admiration for those who rapidly discovered the source of vCJD and recommended the most prudent steps to tackle it. "Credit goes to the scientists – they were on the ball and understood the situation very quickly," says Hiorns. "It was when politicians got involved that things became cloudy and vested interests came into the equation. Essentially, they promoted business interests over public health," he says.

If there is a lesson at all from the crisis, it's that protection of public health should always take precedence, says Hiorns. "You should never feel you're somehow just an expendable node in a causal system," he says. "You get this feeling that governments see the population as a mass, not as a group of individual people."

Paying tribute to those who have already died, Hiorns includes an image of a plaque to their memory on London's Albert Embankment. Soberingly, his part of the exhibition ends by citing recent research, again on appendixes, which suggests that as many as 1 in every 2000 Britons may be infected.

Will we see a new wave of cases in the future, and who is to blame? While it's clear where Hiorns stands, the exhibits invite viewers to make up their own minds. ■

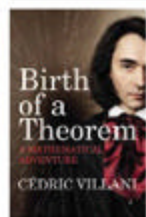
LEFT: PICNIC AT GLYNDEBOURNE, BY TONY RAY-JONES, 1967. PART OF ROGER HIORNS'S CURATED SECTION (PICTURE: NATIONAL MEDIA MUSEUM/SCIENCE & SOCIETY PICTURE LIBRARY/COURTESY ARTS COUNCIL COLLECTION, SOUTHBANK CENTRE)

RIGHT: JØRGEN LETH AND OLE JOHN 'MY NAME IS ANDY WARHOL' FROM 66 SCENES FROM AMERICA (66 SCENER FRA AMERICA), 1982 © THE ARTIST 1982/2014. COURTESY THE ARTISTS AND ANDERSEN'S CONTEMPORARY, COPENHAGEN (PART OF ROGER HIORNS'S CURATED SECTION)

Boltzmann and brio

How much panache can you take from a brilliant French mathematician, asks **Jacob Aron**

Birth of a Theorem: A mathematical adventure by Cédric Villani, Random House, £18.99



I MET Cédric Villani when he visited London in 2011, a year after he had won the Fields medal, the prestigious mathematical

prize awarded to researchers under the age of 40.

As we chatted, I was charmed by the French mathematician's rapid-fire way of speaking, a staccato rhythm that jumped from topic to topic without pausing for breath.

Reading his new book, *Birth of a Theorem*, I instantly recognised that same rhythm. The book covers the few years leading up to his Fields medal win, giving a flavour of the frantic thought processes behind the work that ultimately won him the prize.

The book opens like a film noir, as Villani sits sprawling in his office with intellectual partner Clément Mouhot. The pair are wrestling with a tricky case – not a murder, but the intricate properties of the Boltzmann equation, a statistical description of how particles in a gas behave.

In a tumble of dialogue they bat about phrases like “modulo minimal regularity bounds” and “Moser-style iteration scheme” – essentially incomprehensible to the average reader, but they sweep you along for the ride.

Initially, it's a refreshing alternative to most pop-maths books, which understandably

make every effort to hold your hand as they guide you through tricky concepts. Instead, Villani pours you inside his mind and swirls you around, leaving you with nothing to hold on to and breathlessly wondering what you'll encounter next.

Villani's diary of trips around the world to lecture and research is interspersed with verbatim emails between himself and Mouhot as they attack the problem of Landau damping, a nuance of how waves propagate through a Boltzmann-described

gas. It's interesting to see them at work, even firing off emails on Christmas day, but the text is littered with TeX, a markup language mathematicians use for typesetting equations, which makes it a bit like reading the code of an arcane computer program.

Reams of dense equations pasted in from various academic papers aren't much better, since

“Villani pours you inside his mind, leaving you nothing to hold on to, wondering what you'll encounter”

it's impossible to follow the logic at work without a fairly high level of mathematical training. I ended up just idly flicking through them, wondering if Villani had ever heard Stephen Hawking's quip from the intro of *A Brief History of Time* about every equation halving a book's sales.

Passages about Villani's personal life, like missing French bread and cheese during a stay at Princeton University, are more relatable, but nothing out of the ordinary. Extensive lists of his favourite music and lengthy descriptions of his dreams are as interesting as they sound.

Then there are quotes from poems, song lyrics and Neil Gaiman stories which hint at the varied sources of mathematical inspiration, but it's never quite clear how they connect with Villani's thinking about his research – though with his giant cravat and ever-present spider brooch, Villani himself could have stepped out of a Gaiman novel.

When I met Villani, he told me how most journalists would ask him to do quick mental arithmetic, as if this was all a professional mathematician really did all day. I'd hoped to get a deeper understanding of his work from reading the book, but perhaps that was never the goal.

As a note from the translator says, the book is meant to be an “imprecise recollection”, “a work of literary imagination” and not “a scientific treatise”, and it delivers exactly on this promise. I felt like a passenger inside Villani's head, bombarded by his every thought, both waking and unconscious. Unfortunately, I tired of the ride before I reached the end. ■



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Cédric Villani: looks like he stepped out of a Neil Gaiman novel

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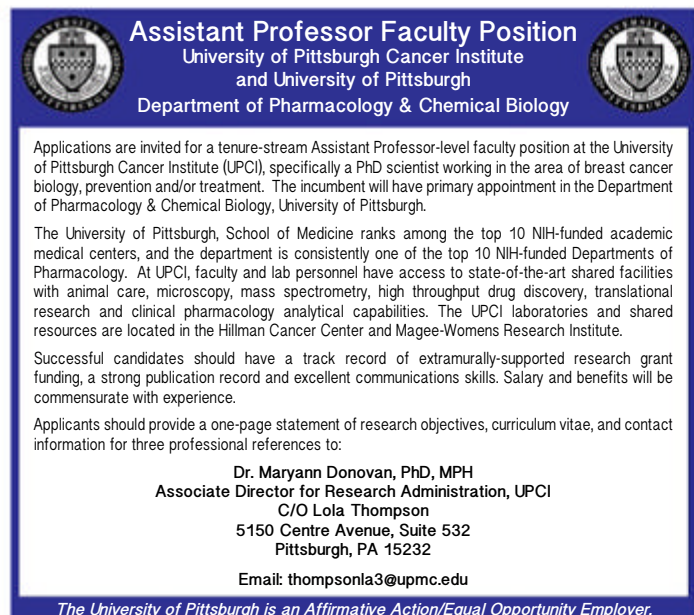
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Applicants should provide a one-page statement of research objectives, curriculum vitae, and contact information for three professional references to:

Dr. Maryann Donovan, PhD, MPH
Associate Director for Research Administration, UPCI
C/O Lola Thompson
5150 Centre Avenue, Suite 532
Pittsburgh, PA 15232
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Bates College, Faculty Position, Biology

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- Biology R2706**

Location: **Lewiston, Maine**

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Application Instructions

Review of applications begins 15 March 2015, and will continue until the position is filled. Applicants should submit in PDF format, a cover letter, curriculum vitae, unofficial graduate transcripts, and statements on teaching and research. Please also arrange for the submission of three letters of recommendation, in PDF format. Employment is contingent upon successful completion of a background check.

Please email academicservices@bates.edu for further consideration, and don't forget to mention you saw us in New Scientist Magazine.



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Application will open in July



Director

Space Telescope Science Institute Baltimore, Maryland

The Association of Universities for Research in Astronomy (AURA) seeks a new Director for the Space Telescope Science Institute (STScI). STScI is located at several sites on or around the campus of the Johns Hopkins University in Baltimore, Maryland. STScI is operated by AURA under contract with NASA to conduct the science program of the Hubble Space Telescope (HST) and to develop the Science and Mission Operations Center for the James Webb Space Telescope (JWST). STScI also operates the Barbara A. Mikulski Archive for Space Telescopes (MAST) for NASA. In the case of HST, the Institute solicits and selects observing proposals, supports observers, plans and carries out the scientific observations, calibrates and archives the data, and distributes grant funding. For JWST, the Institute is currently designing and building the ground system, as well as the systems required to align and maintain the telescope and instruments, in preparation for taking responsibility for both mission and science operations in 2019. STScI is, and will be, responsible for the Education and Outreach activities of both of these very prominent missions.

STScI has a world-renowned professional staff of approximately 600 which includes scientists, engineers, technicians, education/outreach specialists and administrative personnel. STScI's scientific staff conduct world-class research to carry out NASA's missions. STScI is committed to developing and maintaining a dynamic, diverse and inclusive workplace which enables innovation as well as scientific and technical excellence.

The STScI Director is responsible for the overall operation of the Institute within AURA and NASA policies and guidelines. The Director leads all aspects of the Institute. The Director interacts with many stakeholders, including representatives of NASA, the European Space Agency, the Canadian Space Agency, leaders of industry, members of Congress, the astronomical community, oversight committees, Institute staff and the public at large.

The Director should possess broad scientific vision and have established a strong record of achievement and leadership, preferably in astronomy or a closely related field. The Director should also have demonstrated the skills and experience critical for administration and management, and be adept in organizational and international relations. The successful candidate will possess excellent communication and negotiation abilities. The new Director should continue to work with the community to identify potential new missions, carry out studies for them, and to partner with the community to enable such missions. Currently, the Institute is working on concepts for WFIRST/AFTA and next generation space telescopes. The new Director of STScI must be poised to lead the organization, working with our partners, the scientific community and the public through the challenges of transitioning the Institute to HST's successor mission, the James Webb Space Telescope.

AURA/STScI offers an excellent compensation and benefits package. The Search Committee will begin evaluating applications on March 15, 2015. Applications will be accepted until the position is filled. Applications will be held in confidence at the candidate's request. Interested candidates are requested to submit a letter providing a summary of the candidate's interest in the position as well as an overview of the candidate's relevant experience and accomplishments, a curriculum vitae/resume and a list of at least three references. The Search Committee also welcomes nominations.

Materials and nominations should be submitted to directorsearch@aura-astronomy.org and addressed to:

Garth Illingworth, Chair
STScI Director Search Committee, c/o AURA
1212 New York Avenue NW, Suite 450
Washington, DC 20005

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EEO/AA, M/F/Veteran/Disabled

Rocky road ahead

From Chris James

Laws on licensing and liability are important for self-driving cars (14 February, p 20), but nowhere have I seen a discussion of the



most crucial factor: will they be allowed to travel unoccupied?

If they are, it will radically change the way we use our cars. Commuters will no longer pay for expensive town-centre parking when they can drive to work and send their car home, or to a cheap, out-of-town car park, then summon it to take them home again in the evening.

The implications for managing traffic are considerable. And of course, an unoccupied driverless car would make an ideal weapon. Winchester, Hampshire, UK

From Jon Wise

With the news that driverless cars are coming to our roads, should we be discussing what will happen when the car has to choose between the safety of its occupants and the safety of other road users? Should it avoid hitting a pedestrian by steering into a river, for example?

Tewkesbury, Gloucestershire, UK

From Dave McGlade

Hal Hodson underestimates the difficulty that public opinion represents when it comes to self-driving cars. He assumes that if these vehicles can be shown to be safe, people will accept that they are. But that is not how people behave – the fall in vaccination

rates reported elsewhere in the same issue is an example.

Additionally, if the cars are publicly owned, there are issues such as availability, graffiti and cleanliness, all of which would encourage people to have their own autonomous car. Thus the impact of this technology on reducing congestion will be negligible. Technical problems, however hard they appear, are rather easier to solve than those requiring a change of habit, attitude and culture.

Southampton, UK

From Martyn Thomas

Changes in human behaviour may make driverless cars unusable. Why would you wait to cross the road, or pull out at a junction, if you know that the approaching cars are programmed to give way? London, UK

Name that festival

From Markus van der Burg

In writing about the origins of the Up Helly Aa festival in Shetland, Dan Jones writes that “nobody knows quite where the name came from or what it means” (17 January, p 36).

It may just be that no one needed to ask, because with a touch of mutated spelling, a modern day Swede would say “uppför den heliga å”, or “up the holy stream”, while a Dane would say “up den hellig ånde”, which participants may prefer given that it translates to “up the holy spirit”. Norwegian and Faroese speakers may improve on this.

London, UK

Family strife

From Mary Voice

Manuel Eisner’s fascinating article shows that many forms of violence are avoidable in our societies (7 February, p 26).

Two other factors are likely to

contribute to reducing violent crime, which could be included in thinking and planning for future efforts to do so.

First, no-fault divorce allows couples to separate in a civilised way, and frees some from domestic violence traps.

Second, the contraceptive pill reduces unwanted pregnancies and allows more families to raise successful families within their means, leading to lower rates of delinquency.

While these factors are obviously not a panacea, they perhaps deserve consideration in the overall mix of community and social planning.

Ivanhoe, Victoria, Australia

Also, companies buying the processing power will invariably switch to newer users with newer and faster kit. Early Exergy adopters will be abandoned, leaving them with nothing more than expensive electric heaters.

London, UK

From Steve Hitchen

Hal Hodson writes that “using our computers generates plenty of waste heat. Time to harness it to warm our houses”. Isn’t warming my house what my desktop, home server, laptop and various other devices do already?

Stocksfield, Northumberland, UK

Snow the distance

From Paul Coyne

Michael Berkson writes to bring attention to the patents filed by Arthur Pedrick, one of which proposes transporting fresh water from the polar ice caps to desert regions by means of snowballs drawn through a large pipe (31 January, p 55).

Your cartoonist illustrated this with a polar bear arriving in the Australian desert atop one of the rolling snowballs.

Might I suggest that the delivery of snow to Australia would be more efficient if Antarctica were the source? This would reduce the delivery distance by 6000 kilometres or thereabouts, a handsome saving I’m sure you’ll agree. Glasgow, UK

Landing in hot water

From Adrian Ellis

The plan to sell home data centres to customers as heat sources sounds innovative, but seems to be missing some key financial points (7 February, p 20).

Each customer will need to sell the extra computing power online. The cost of a high-bandwidth connection to the internet, and an intermediary to allocate the processing tasks, is not mentioned.

More importantly, the article doesn’t mention Moore’s law,



which states that computing power doubles every two years. This means that the expensive kit a Project Exergy customer buys will roughly halve in value every two years.

Helium reserves

From Richard Clarke

Andy Ridgway is right to draw attention to the supply of rare earth elements for use in smartphone electronics (14 February, p 35).

But the utility of these elements depends on a chemically-inert dopant carrier and heat transfer gas: helium. This element should also be

included as a critical raw material.

Helium has been almost completely overlooked by policy makers outside the US. That is a mistake. Mostly co-produced with natural gas, good quality helium resources are finite. Unlike the solid rare earths, once used helium is massively diluted by the atmosphere before being lost into space. The extraordinary helium molecule deserves to be added to the European Commission's "EU 14" list of critical materials. *Abingdon, Oxfordshire, UK*

Big city cows

From Brian Bennett

There is a historical precedent in producing food in cities (14 February, p 30). As the size of cities grew at the end of the 19th century, the time to transport milk into cities from the countryside also grew. With no refrigeration the milk frequently went sour before it reached customers.

This led to the growth of cow-keepers, who produced milk in dairies within the bounds of many cities. When the cow was not "in milk" it was returned to the countryside. The rise in refrigeration eventually led to the end of this business. *Lathom, Lancashire, UK*

Science buzz

From Don Michels

The question of whether a truck becomes lighter if its cargo of birds takes flight was answered definitively in 1961 by some fellow graduate students at the Colorado School of Mines (24 January, p 13).

We captured a honeybee in a small glass jar with a tight-fitting lid and placed the assembly on a scale that was sensitive to 0.1 milligrams. With the lid on tight, the balance was absolutely steady, regardless of whether the bee was clinging to the sides or hovering.

However, when we loosened the lid, the balance was lighter when the bee was hovering. *Missoula, Montana, US*

Airborne launch

From Oliver Arditi

Your brief report gives the impression that launching satellites into orbit from an aircraft would be a novel approach (14 February, p 21).

This has in fact been routine for the last 24 years. The Pegasus launch vehicle built by Orbital Sciences Corporation is launched from an airliner at 12,000 metres.

It has carried out 37 successful launches to orbit since its inception in 1990, delivering loads roughly 10 times as large as the new system mentioned in your report.

Stoke-by-Nayland, Suffolk, UK

Intelligent by design



From Russell Robles-Thorne

It is a nonsense to submit to the voodoo that says germ-line therapy is necessarily a bad thing (14 February, p 26).

Given the rate of progress in gene sequencing, it could soon be practical to combine pre-implantation genetic diagnosis with IVF. This would allow parents to choose the genes of their children by selecting from a small number of embryos. The cost could be comparable to cosmetic surgery, and a fraction of the cost

of a private education. Who would not choose to do so?

The problems are dealing with the plethora of information to make sensible choices, and making access equitable. It would be disastrous if this became a privilege of the rich.

This should be available to all through the UK's National Health Service, which will also be in a position to gather data to provide good guidance.

In regards to selecting for Einsteins: although we don't know how to do it yet, why not, in the end? I'm an optimist. I think parents will choose children who are likely to be healthy, wealthy and wise – to everyone's benefit. *Edinburgh, UK*

From John Hood

In view of some people's concern for the inaccuracy and emotive connotations of the term "three parent babies", how about "melange à trois" instead? *London, UK*

Aiming high

From Martin Pitt

Hal Hodson reports on SAFFiR, a firefighting robot built for the US navy (14 February, p 22). Inventor Meredith Thring also developed one in the 1960s, while at the University of Sheffield.

This autonomous machine was intended as a nightwatchman in factories, following a pre-programmed route and investigating and dealing with any fires it detected.

A demonstration was given to the Duke of Edinburgh in 1961 at the opening of our new building.

However, working outside in daylight raised an issue. On its way to deal with the test fire, the robot's camera spotted the sun.

Correctly determining this was much hotter, it turned its attention to the more serious fire and bravely tried to extinguish the sun.

University of Sheffield, UK

Known unknowns

From Chris Ford

Steven Miles claims that agnosticism is an untenable position (21 February, p 54). As I understand it, agnosticism is not a "don't know" position, but the assertion that the existence of god is unprovable. This is a more scientific position than either atheism or theism can claim to be. *Walsall, West Midlands, UK*

True colours

From Paul Bowden

So lilac and turquoise have been designated "basic colours", recognised universally among English speakers (7 February, p 16).

It's nice to have two new colours. On the other hand, I've never considered pink to be a fundamental colour. After all, it's just light red, really. Isn't it time that pink was downgraded to "dwarf colour" status? *Nottingham, UK*

Slice of life

From Neil Hogben

I believe there is a reason behind time appearing to speed up as we age (31 January, p 54). It is simply that the perceived duration of a defined period of time depends on the proportion of our life to date it would represent. I am now 91, so according to this idea each year seems to last about 10/91 (or about 10 per cent) as long as when I was 10. I can confirm that this is about right.

Claygate, Surrey, UK

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NOMINATIVE determinism is the name given by the late C. R. Cavonius, of the Leibniz Research Centre for Working Environment and Human Factors in Dortmund, Germany, to the notion that names influence occupations (17 December 1994). He was inspired by Jen Hunt, who wrote in *The Psychologist* that “Authors gravitate to the area of research which fits their surname” (5 November 1994). She had cited an article on incontinence in the *British Journal of Urology* by A. J. Splatt and D. Weedon (vol 49, p 173).

Since then, the phenomenon has garnered mentions in science blogs, magazines and newspapers – and, inevitably, randomnesses such as the column in *The Times* from 23 January this year, in which Caitlin Moran discussed “the nominative determinism breaks of having something that invokes the phrase ‘into darkness’ right over your lady-area”. How does that work?

PAUL McDEVITT

IN 1994 we called for “rigorous scrutiny” of nominative determinism. Eventually, we found a paper by researchers at

the State University of New York at Buffalo making a start on that: “Why Susie sells seashells by the seashore: Implicit egotism and major life decisions” (1 December 2007). And the *BMJ* has reported a correlation between surnames and health (22 February 2014).

Attempting to leave the subject to develop quietly by itself into an academic specialism, we have frequently abjured and renounced it (26 April 2014). The result is that we have a backlog of 215 nominative nominations.

MINING this pile of nominative determinism pretty much at random, we find that the optometrist Hugh Seymour (18 September 1999) is now complemented, in an ad that Peter Duffell sent, by Peter Fogg – a dispensing optician.

AND who would be head of pain at Mundipharma in Cambridge, UK? Kate Hurtig, Meredith Lloyd-Evans tells us. Dave Frankland mentions the vet at the Perth Cat Haven in Australia, Dr Pusey. Still

on a medical trip, Robin McKellar informs us that his first wife’s obstetrician was Dr Nurse and his second wife’s Dr Blood.

WHILE we were writing the above, a colleague sent an assessment of the feasibility of zapping missiles with “death ray” laser weapons, quoting one Mark Gunzinger.

AND who, David Smith asks, better to speak on climate change than Robin Frost and Hugo Winter? A colleague sends congratulations on an award to a volcanologist at the University of Bristol in the UK, Stephen Sparks. Bryn Glover approves of the career choice of Ben Winger, who studies American songbirds (9 August 2014, p 9).

IT MAY not just be researchers who are affected, it seems, but also the objects of their study. Barrett DiPaolo points out that the first vertebrate to copulate was the fish *Microbrachius dicki* (25 October 2014, p 9).

LORD FINK has recently been in the news in the UK, quoted as describing his tax avoidance as “vanilla”. As we went to press, he was not suing anyone for mentioning him in this context.

IF LORD FINK changes his mind again, he could possibly engage James Lawless, a barrister who came to Drew Ogden’s attention when he stood for election in the town of Naas in Ireland’s County Kildare. James could be instructed by solicitors Wright Hassall (21 June 2008). Sadly, the case will not be heard by the charming Igor Judge, who our editor-in-chief Jeremy Webb put up for **Feedback** but has since retired as lord chief justice of England and Wales.

MENTION of barrister Lawless and the optician Fogg returns us to nominative contradeterminism. David Ridge responded to our last mention (26 July 2014) to suggest it be called “ablative determinism”, and mused what vocative, accusative, genitive and dative determinism might be. Now Ewan

MacGregor tells us that Jeff Fridge manages Inverness Crematorium in the UK.

FEEDBACK readers being who you are, we can complete the set. In between nominative determinism and nominative contradeterminism lies non-determinism. Julian Cockbane asks whether people named Brown, Schmidt and Singh find their careers a bit undetermined. (We dare not ask what Julian does.)

FINALLY, it is rare that **Feedback** empathises with UK tax officials. But on 13 February, whistleblower Herve Falciani produced the 2008 email in which he told them he had information on secret Swiss bank accounts – including that of Lord Fink.



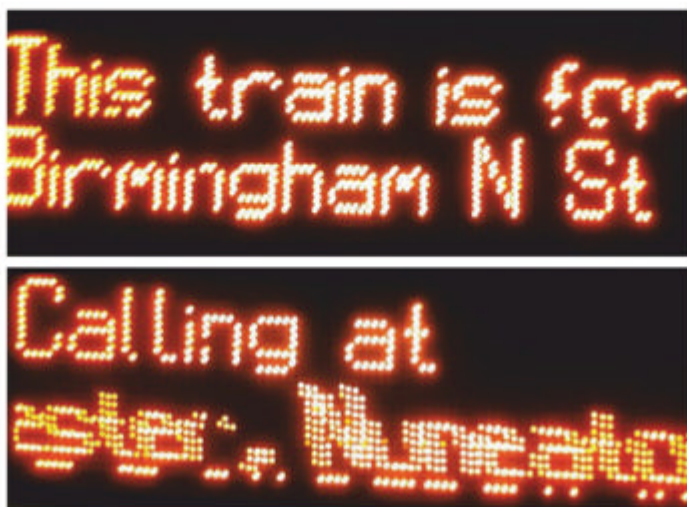
He sent it from toomuchwalls@yahoo.fr to enquiries.estn@hmrc.gov.uk – a generic address. It read: “I have the whole list of client of one of the world top five private bank. 1/ This bank is based in Switzerland. 2/ I’m also granted to access to the Information System.” Some colleagues swear they would assiduously follow this up, after considering whether doing so would involve further offences under the Computer Misuse Act 1990. **Feedback** shamefacedly confesses that we’d likely have filed it under “scams”.

You can send stories to **Feedback** by email at feedback@newscientist.com. Please include your home address. This week’s and past **Feedbacks** can be seen on our website.

“How to make delicious caviar from sparkling water”, reads an email to **Feedback**. We haven’t investigated further, suspecting it’s an attempt to infect us with a computer virus, only pretending to be fruitlooper

Sloping off

On my train to work there is a dot-matrix sign which has the words "Calling at" in a Roman font, but the station names below it in italic font. However, if you take a photo of the sign all the words appear Roman (see photo, top). If the photograph catches the sign at the correct moment, you can see that the italic font is created by the dots on the sign lighting up with some clever on-off timing that fools the eye (see photo, bottom). All the dots are in vertical and horizontal rows. How is this italic effect created and, more intriguingly, why bother?



■ The italic effect that the questioner describes is not created deliberately. It is an accidental result of the way the dot-matrix display works, through a technique called multiplexing.

The number of LEDs in the display is large – easily in the thousands – and it would be expensive to use a separate electronic driver to control each one. Instead, the lights are controlled by column and row. Each LED is illuminated by powering its column and row drivers at the same time – a bit like the game *Battleships*. And although the display appears to be illuminated steadily, it is actually flickering at a high speed, with only one row lit up at a time.

This is fine until it becomes necessary to show a moving line of text. To avoid the words distorting in this case, the display

would have to flash its entire sequence of rows – perhaps 25 of them – before the letters changed position. By using this method, the text would appear to move only very slowly.

If the text is to speed up, the display only has time to illuminate a few rows (or maybe even just one) before the position of the letters changes. When the subsequent row flashes up, the text has moved a little to the left or right, and this leads to the apparent sloping lines.

The alternative is to refresh the display one column of LEDs at a time, but this would make the distortion even worse. Instead of an acceptable italic slant, the characters would appear to be squashed or expanded and would not be legible.

The reservation displays above seats in some trains demonstrate the problem, with the text

seeming to move infuriatingly slowly. There could be several reasons for this, but one may be that the displays are driven a column instead of a row at a time, meaning that fast-moving text cannot be accommodated at all.

*David Gibson
Leeds, West Yorkshire, UK*

Zzzzzzchooo...

Why don't we sneeze in our sleep?

■ A sneeze is a reflex reaction – an involuntary response to an internal or external stimulus. Reflex reactions shut down during sleep because of rapid eye movement (REM) atonia, a physiological state during which movement messages can't get from the brain to the muscles, causing partial paralysis. This prevents sleepers

from acting out their dreams to the detriment of themselves or their bed partners. A consequence is that reflex signals are not acted upon, so there's no sneezing during sleep. If a sneeze is absolutely necessary, REM atonia ceases and the person wakes up before sneezing.

There have been cases of REM sleep behaviour disorder in which people acted out their dreams and ended up in court after injuring or killing their partner. Presumably, such people can sneeze in their sleep.

*David Muir
Edinburgh, UK*

■ It is a leading question, implying that "we" means all of us. I do sneeze during my sleep, frequently if I have a head cold. This wakes up my wife, who then awakens me and tells me that I have disturbed her sleep by sneezing yet again.

Presumably if I slept by myself, I would not have woken up. And the implication of this is that only couples are known to sneeze while they are asleep. Now, there is a PhD project.

*Ron Pursell
Flookburgh, Cumbria, UK*

This week's question

GLOOMY-SIDE UP

Whenever I make scrambled eggs, they turn out grey. What causes this?

*Les Moore
Hartford, Cambridgeshire, UK*

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